Facies Analysis And Sedimentation Trends of Late Paleozoic Talchir Sediments in Son-Gondwana Belt, North of Korba, East-Central India

BY

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ABSTRACT

THESIS SUBMITTED
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ABSTRACT

The area under investigation lies in the central part of the western margin of Son-Mahanadi Gondwana belt and extends from Korba to Korbi in the State of Madhya Pradesh, occupying about 4028 square kilometers.

The Talchir sediments of Korba and Hasdo-Arand coalfields are the subject matter of the present study and have been investigated in respect of their lithofacies, petrography, paleodrainage patterns, provenance, basin geomorphology and depositional environments.

Detailed field work by the author during the winter months of 1981, 1982 and 1983 has revealed that the Talchir sediments of the area comprise of seven basic types of lithofacies, namely, massive (basal) diamictite, laminated mudstone with or without dropstone, inter-bedded shale-siltstone/ sandstone, massive sandstone, splintery shale, stratified (upper) diamictite and cross-stratified sandstone. Study of the vertical and lateral variations in lithofacies reveals that the nature and pattern of variation is directly related to the geomorphic position of measured section in relation to the basin margin. Sequences developed at or near the basin edge are thin and give evidence of having been deposited in shallow, isolated bodies of standing water while those

representing the more distal parts of the basin, are much thicker, more diversified and appear to have been deposited in deeper and bigger lakes.

The petrographic study of the diamictite units and sandstones of Talchir Formation provides valuable information regarding their mode of formation. The massive diamictite which invariably occurs at the base of the Talchir sequence, is poorly sorted and comprises of clasts of pebble-, cobble-, and boulder-grades set in an abundant green coloured, predominantly clayey, matrix. Studies made on 1593 clasts of this diamictite unit reveals that they have a coarse skewed unimodal size frequency distribution. On an average the clasts are subangular to subrounded (average roundness 0.306) althrough about 14% of them are rounded to well rounded. The most commonly occurring shape of clasts is compact bladed (32%). The average sphericity of clasts is 0.72. Quartzite (33% to 46%), granite and gneiss (27% to 34%) and sandstone (17% to 23%) constitute the most abundant lithologies occurring as clasts in the massive diamictite. Other lithologies occurring in minor amounts are greenstone and basalt, limestone and chert and low grade metamorphic rocks. The matrix of the diamictite is moderately sorted, generally fine skewed, mesokurtic and shows a bimodal size frequency distribution. In composition it varies from sublith-wacke to subarkosic-wacke.

The upper diamictite unit is stratified but resembles the massive diamictite in its textural and compositional characteristics. However, it differs from the massive variety in some important respects. Thus, the clasts of this diamictite unit are smaller in size, more fine skewed and about 23% of them are rounded to well rounded (average roundness 0.328). The matrix of the stratified diamictite is sandy, shows unimodal size frequency distribution and its composition varies from sub-litharenite to sub-arkose. Further, it contains more quartz and feldspar and lesser amount of labile rock fragments as compared to the massive (basal) diamictite.

The sandstone of the Talchir Formation are sub-litharenite and sub-arkose and show close resemblance to the matrix of the diamictites inasmuch as the chief modal constituents are concerned. However, they show remarkable uniformity of texture and composition. On the basis of their mode of occurrence and sedimentary characters, the sandstones have been grouped into three facies, namely, massive, cross-stratified and inter-bedded. All sandstone types are fine to very fine grained but whereas the massive sandstone shows variable size frequency distribution from unimodal to trimodal, the other two types are unimodal. By and large, the cross-stratified sandstones are better sorted than the other types. Grains constituting the sandstones are, on an average, subrounded.

It is interesting to note that the heavy mineral assemblages contained in the sandstones and in the matrix of the diamictites are almost identical both in respect of quality and quantity. Indeed from the point of view of mineral composition, the sandstones and the matrix of the diamictite units show very close similarity suggesting a common source of supply of detritus through time and, therefore, suggesting tectonic stability during Talchir sedimentation

The paleocurrent systems existing during the Talchir times have been reconstructed on the basis of orientation of long axes of clasts in the two diamictite units as well as on cross-stratification foreset dip azimuths and alignment of channel axes in sandstones. During the deposition of massive (basal) diamictite, the depositing agency moved in a general easterly and northeasterly direction at or near the margin of the basin. Further basinwards, the direction changed to northerly and northwesterly. In most outcrops studied the degree of preferred orientation is significant. Two mutually perpendicular modes are seen and their pattern resembles those observed in glacial tills.

The paleoflow pattern obtained from the fabric study of stratified (upper) diamictite is significantly different from the one just described. The long axes of clasts generally show unimodal frequency distribution and outcrop to outcrop variation in mean orientation direction is restricted within 79° of arc (in contrast to 89° of arc in basal diamictite). Further, the scatter of variance (S^2) values in the upper diamictite is much less as compared to basal diamictite and ranges from 2000 to 3000 in 10 outcrops out of 12 studied. These values, as well as the fabric patterns, are comparable to those associated with stream gravels.

The sediment dispersal pattern obtained from cross-stratification foreset dip azimuth data and orientation of channel axes in sandstones is compatible with the pattern existing at the time of deposition of the stratified (upper) diamictite. It seems that a fluvial system was well established during the closing stages of Talchir sedimentation in the study area.

Based on paleocurrent studies, a southwesterly to westerly source area for the Talchir sediments is indicated. The pre-Gondwana rocks exposed in the indicated area are granite and gneiss of Archaean age, quartzite, quartz schist, mica schist, garnetiferous schist and slate with inter-bedded greenstone and traprock belonging to the Chilpighat "series" (Lower Pre-Cambrian) and red coloured quartzose sandstones shales and limestones of the Chhattisgarh basin (Upper Pre-Cambrian). The clast lithology of the two diamictite units as well as the mineral composition of the Talchir sandstones and matrix of the diamictites is perfectly compatible with the rocks present in the suggested provenance indicating that the later did indeed serve as the source rocks for the Talchir sediments.

The present day distribution of the Talchir rocks in the study area, the nature of vertical and lateral variation in lithofacies in the proximal and distal parts of the basin and the changing patterns of paleodrainage through time, suggests that Talchir sedimentation in the area under investigation was initiated in small and big sub-basins or lakes on the floor of the basin. In the proximal part of the main basin, sedimentation took place in small, shallow lakes and consequently the thickness of sediments laid down was small. However, in the distal and deeper parts of the basin, the lakes were deeper and more extensive resulting in the accumulation of a thicker and more diversified lithic fill.

Presence of striated pavement in the study area, occurrence of dropstones in fine clastics, varves and associated lithologies in neighbouring areas and presence of shaped clasts in diamictites and roché s moutonneé s on basement rocks are evidences in the face of which a glacigene origin of the Talchir sediments cannot be disputed. Thus, in the study area a glaciolacustrine environment of deposition is envisaged to explain most of the lithofacies. However, towards the end of Talchir sedimentation, a fluvioglacial environment is visualised on the basis of sandstone facies and paleocurrent patterns.

Sedimentation started in the Talchir basin with the deposition of the massive (basal) diamictite which has been interpretted as a basal till laid down on the edge of proglacial lakes. The fine clastics brought into the lakes was deposited as laminated mudstones while clasts were dropped from floating ice sheets into the fine clastics. In some areas, an inter-bedded sequence of shale and siltstone/fine sandstone was deposited giving evidence of slight shallowing of the basin and consequent reworking by weak currents. The laminated mudstone and inter-bedded sequences pass into massive, fine to very fine grained sandstone indicating rapid sedimentation and further shallowing of the basin.

In the marginal parts of Talchir basin, the massive sand-stone passes into cross-stratified sandstone indicating the advent of fluvioglacial conditions. However, in the distal parts of the basin, the massive sandstone gives way to a thick sequence of laminated, splintery shale suggesting that lacustrine conditions still persisted in the deeper parts of the basin. Reworked coarse glacial debris was then deposited in glacial streams which now is represented by the stratified (upper) diamictite. The presence of cross-stratified sandstone capping the Talchir sequence in most of the sections studied, indicates the total disappearance of lacustrine conditions and the establishment of truly fluviatile conditions and marking the end of Talchir sedimentation in the study area.

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DEDICATED TO MY
LATE GRAND MOTHER

CHAIRMAN

DEPARTMENT OF GEOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH-202001

Date 27.7.1987.

CERTIFICATE

This is to certify that Mr. Abrar Ahmad has carried out this investigation on "Facies Analysis and Sedimentation Trends of Late Paleozoic Talchir Sediments in Son-Gondwana Belt, North of Korba, East-Central India" under my supervision for the award of the degree of Doctor of Philosophy of the Aligarh Muslim University, Aligarh. The work is an original contribution to the existing knowledge of the subject.

He is allowed to submit the work for the award of the Ph.D. degree of the Aligarh Muslim University, Aligarh.

PROF. V.K. SRIVASTAVA
Chairman

Department of Geology,
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ALIGARH-202001.

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INTRODUCTION

0.1. GENERAL REMARKS

The thick sequence of essentially fresh water sediments, ranging in age from Permo-Carboniferous to Lower Cretaceous is referred to as the Gondwana Supergroup in Indian Stratigraphy. Though the bulk of Gondwana rocks are of fresh water origin, evidence of marine incursions in the lower most part of the sequence has been recorded at Manendragarh, Umaria and Daltonganj Coalfield.

The Gondwana rocks of peninsular India occur as outliers along well defined, narrow, long belts on the Pre-Cambrian platform following prominent basement lineaments and coinciding with the four present day major river valleys from which they derive their name. The major Gondwana basins include Koel-Damodar, Son-Mahanadi, Pench-Kanhan and Pranhita-Godawari belts (Fig. 1). In addition to these there are some other areas that lie distinctly outside these belts along the foot-hills of Himalayas but the occurrences are minor and insignificant.

In all Gondwana basins the basal part of the sequence, referred to as the Talchir Formation, is very different from the rest of the sequence. At and near the base of this

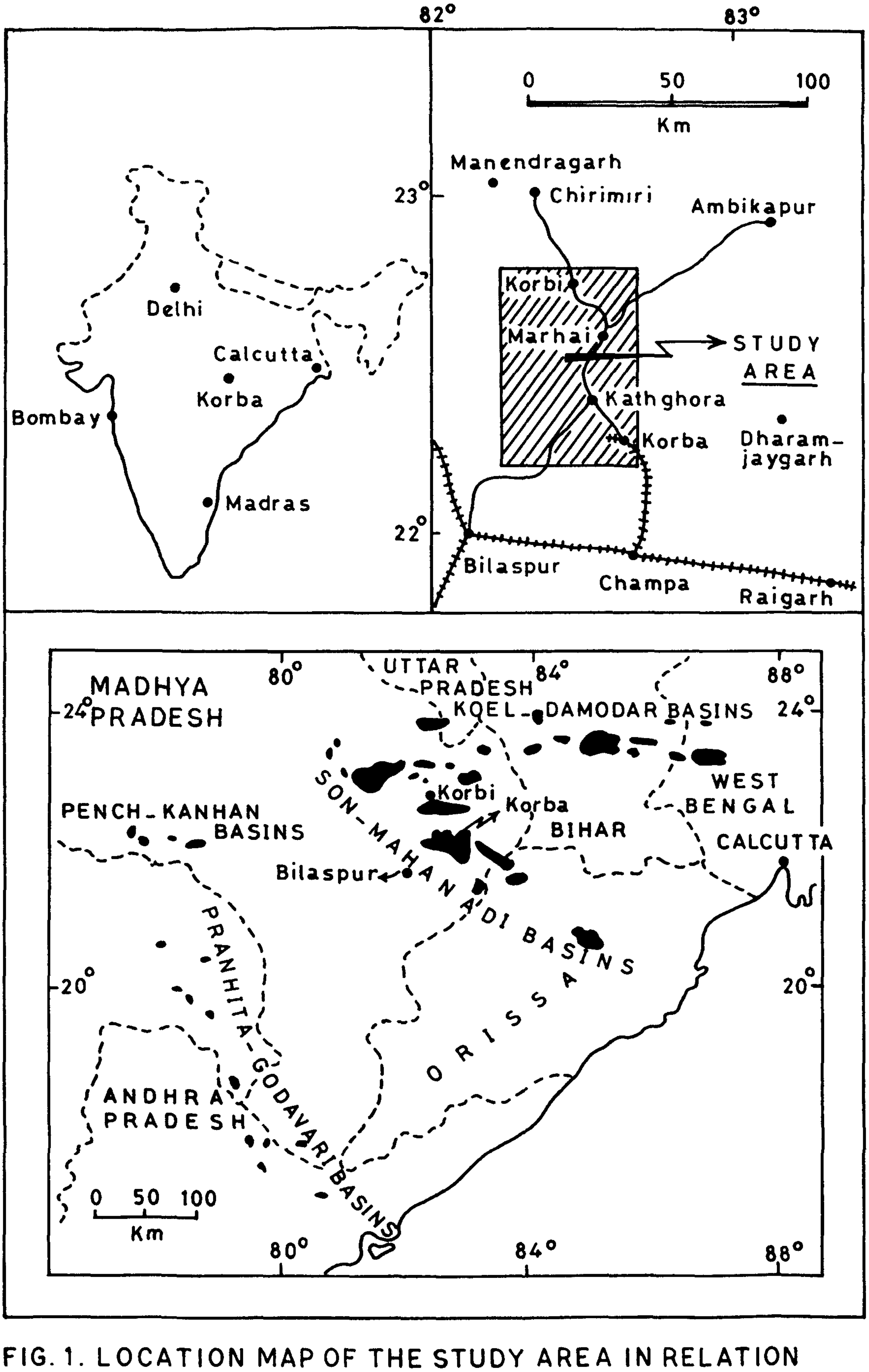

FIG. 1. LOCATION MAP OF THE STUDY AREA IN RELATION TO THE MAJOR GONDWANA BELTS OF PENINSULAR INDIA.

Formation are two or more diamictite units which are believed to be a record of a very wide spread glaciation. However, the bulk of the Talchir Formation comprises of green, fine grained sandstones and siltstones and green splintery shales. Indeed, the green color is characteristic of all the facies constituting the Talchir Formation.

Interest in the nature and origin of the Talchir sediments, specially the diamictite units, dates back to almost the time when the Gondwana basins were first discovered and the search for coal started in India (Blanford, 1872). While it is true that the coal-bearing formations of the Gondwana Supergroup attracted by far the greatest interest, pioneer workers, as early as late 19th century and early 20th century, made various attempts to understand the environmental conditions in which the Talchir sediments were deposited (Blanford and others, 1856; Hughes, 1867; Ball, 1867; Oldham, 1893; Simpson and Ball, 1922; Jowett, 1925; Fox, 1930, 1931a, 1931b, 1934; Gee, 1932). The investigations carried out by the earlier workers were basically qualitative and based essentially on field studies and wide experience. Although divergent views were expressed by them on the question of the origin of the Talchir sediments, their works are classic and many concepts generated by them still hold good and have withstood the test of modern techniques of the study of sediments.

Today a great volume of literature has accumulated on various aspects of sedimentation of the Gondwana deposits of

India including the Talchir Formation. References are too numerous to be listed here and the interested reader is referred to Volumes I and II of the Fourth International Gondwana Symposium held in Calcutta in 1977 under the auspices of the Geological Survey of India.

The Talchir Formation occurring in the central part of Son-Mahanadi Gondwana belt is the centre of interest of the present study.

0.2. LOCATION OF THE AREA

The area covered by the investigation is approximately 4028 square kilometers and situated about 40 kilometers north of Champa railway station and 72 kilometers northeast of Bilaspur town in Madhya Pradesh (Fig. 1). It lies between the North Latitudes of 22°15' and 22°55' and East Longitudes of 82°15' and 82°45' and falls within the one inch to a mile scale Survey of India topographic sheet numbers 64 J/5, 64 J/6, 64 J/9, 64 J/10, and 64 J/11.

The area is well connected by road with the towns of Bilaspur, Korba, Chirimiri and Ambikapur and can be easily approached by bus and other means of road transport.

Geologically, the area lies mainly in the Hasdo-Arand coalfield and partly in the Korba coalfield.

0.3. PURPOSE AND SCOPE OF INVESTIGATION

The Talchir sediments of the Korba and Hasdo-Arand coalfields are very extensively exposed in the area under investigation. In many ways the geomorphic setting in which the Talchir sediments were deposited in this area is unique. The area lies on the western edge of the main NW-SE trending Son-Mahanadi Gondwana belt and provides information about the basement topography on which the Talchir sediments were deposited. Good sections of the Talchir sequence are exposed in the subsidiary, shallow transverse valleys, as well as in the marginal part of the main valley, thereby providing an opportunity to study the variations in facies through space and time and also the dispersal patterns of the sediments under a complex geomorphic set up.

The present investigation aims at examining in detail the lithic fill of the Talchir Formation with special reference to lithofacies, their sedimentary characters, sediment dispersal patterns,texture and petrography. The author believes that this investigation will be helpful in further understanding the patterns of Talchir sedimentation in this part of the country.

Field work in the area was carried out during the winters of 1981, 1982 and 1983. The geological map of the area published by Choudhury (1977) was taken as the base, but suitable corrections and modifications were made in the map during field work.

All accessible stratigraphic sections were measured and studied for their lithologic, petrographic and sedimentary characters. Special attention was paid to the study of the diamictite units in the various sections. The clast lithology, mechanical composition, roundness, shape and sphericity, and the spatial orientation of the clasts were measured, plotted and data statistically treated. The fine fraction of the diamictite was subjected to thin section studies which included the determination of textural and compositional attributes. The sandstones were studied in the same manner as the matrix of the diamictite. The paleocurrent study was based on the orientation of long axes of clasts in diamictite units and cross-stratification dip azimuth orientation in sandstones. Channel axes in sandstones were also measured and plotted to supplement the paleocurrent data. Based on the above, a paleocurrent map of the area was prepared.

The study of the probable provenance which supplied sediments to the basin is based on the sediment dispersal patterns, clast lithology and heavy mineral investigations of the various lithostratigraphic units. An attempt has been made to work out the depositional environment in which the Talchir rocks of the study area were laid down.

0.4. ACKNOWLEDGEMENTS

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CHAPTER - 1

GEOLOGIC SETTING AND STRATIGRAPHY

1.1. HISTORICAL REVIEW

The Son-Mahanadi Gondwana belt extends for a little more than 520 kms from the Talchir coalfield in Orissa, through Korba, Chirimiri and Bisrampur in Madhya Pradesh to Singrauli Coalfield which lies partly in Madhya Pradesh and partly in Uttar Pradesh. Eighteen Coalfields lie in this belt, each being named after the geographical location of its coal bearing formation. This belt covers an area about 25,000 sq. kms.

The study area lies on the western margin of the central part of the Son-Mahanadi Gondwana belt and forms part of the Korba and Hasdo-Arand Coalfields. It may be pointed out that the Talchir sediments of the two coalfields form continuous outcrops but the two coalfields are separately named because the coal measures in the former lie around the town of Korba and in the latter in the catchment area of the Hasdo and Arand rivers.

According to Fox (1934, p. 224), Dr. V. Ball seems to be the first geoscientist to have visited the coal bearing area of what is known today as the Hasdo-Arand Coalfield in 1870-71. He further states that Lala Hira Lal of the Geological

Survey of India, examined this area in 1885-86 and 1887-88. Fox (1934) investigated this area mainly from the point of view of delineating the limits of the coal measures and estimating the reserves of coal. He also analysed the coals of the area and described some sections of the coal measures. Ghosh (1953) investigated a part of this coalfield with special reference to coal bearing strata. Puri (1971) studied the coal measures of the Hasdo-Arand Coalfields but hardly touched upon the general geology of the area.

The coal bearing sediments of the area which constitutes the Korba coalfield, were first recognised by Blanford (1870) and, according to Fox (1934, p. 232), examined by Lala Hira Lal in 1886-87 who discovered several coal seams in the area. Simpson (1922) and Fox (1934) made detailed investigations of the coal seams in the area but gave no account of the general geology as such. Ghosh (1971) summarised the geology of the Korba area but the main emphasis of his work was on the coal potential of this coalfield.

1.2. CLASSIFICATION OF GONDWANA ROCKS

The classification and stratigraphic nomenclature of Gondwana sediments of India have been matters of debate and revision from time to time. Sastry *et al*. (1977b) have reviewed this aspect of the study of the Gondwanas.

The first official classification of these rocks was presented by Meddlicott and Blanford in 1879 (See Fox, 1931, p. 78) based mainly on paleobotanical evidence and comprised of a two-tier scheme dividing the rocks into the Lower and Upper divisions. A slightly updated form of this classification (Fox, 1934, p. 10) is presented in Table 1.

Table 1 : Two-fold classification of Gondwana Rocks (after Meddlicott and Blanford, 1879).

Lower Cretaceous		Umia plant beds		
	Upper	Jabalpur stage		
Jurassic	Middle	Kota stage		Upper Gondwana
	Lower	Rajmahal (inter-trappean plant beds)		
	Rhaetic	Bagra, Denwa stage	Mahadeva series	
Triassic				
	Keuper	Pachmarhi		
	Bunter	Panchet series		
	Upper	Raniganj		
Permian	Middle	Barren measures	Damudas	
				Lower Gondwana
	Lower	Barakar series		
Upper Carboniferous		Talchir series with glacial boulder beds		

In this classification, the Lower division is characterised by 'Glossopteris flora' while the Upper is characterised by 'Ptilophyllum flora'. The two divisions are supposed to be separated by an unconformity representing a paleontological and stratigraphic break. This classification with some modifications, has found favour with most workers in the field of Gondwana geology (Oldham, 1893; Cotter, 1917; Fox, 1931, 1934; Krishnan, 1968; Pascoe, 1959; Bose, 1966; Bakshi, 1967; Ghosh and Basu, 1969; Kutty, 1969; Mitra, 1972; Casshyap and Srivastava, 1986; etc.).

However, the presence of arid continental deposits containing Triassic reptiles and amphibians in the middle part of Gondwana sequence overlain and underlain by sediments indicating humid and warm conditions and on the basis of occurrence of Discroidium flora in Parsora Formation, led Feistmantel (1882) to propose a three-fold classification of Gondwana rocks comprising of the Lower, Middle and Upper divisions and corresponding broadly to Permian, Triassic and Jurassic System of Europe. He included the Panchet sub-division within the 'transitional beds' whose flora show close affinity to the Lower Gondwanas but appears lithologically more akin to the Upper Gondwanas (Sastry et al., 1977a). The tripartite classification has been adopted by Vredenburg (1910), Wadia (1939), Saxena (1952, 1974), Lele (1962, 1964), Roychowdhry et al (1973). The three-fold scheme of classification is presented in Table 2.

Table 2 : Three-fold classification of Gondwana Rocks (after Feistmantel, 1882).

Upper Gondwanas	Umia		Lower Cretaceous
	Jabalpur Rajmahal		Upper Jurassic
	Kota		Lias
Middle Gondwanas	Maleri		Keuper and Rhaetic
	Mahadeva		Muschelkalk
	Panchet		Bunter
Lower Gondwanas	Damuda	(Raniganj	Upper Permian
		(Barren Measures	Middle Permian
		(Barakar	
	Talchir		Upper Carboniferous

Among the two classifications presented above, the two-fold classification of the Gondwana rocks is more popular amongst the workers and has been adopted by the Geological Survey of India.

1.3. STRATIGRAPHIC NOMENCLATURE

A review of the Gondwana literature shows that the hierarchical terms used for the description of the various large and small units of the stratigraphic column show no uniformity. Thus terms like 'System', 'Series', 'Stage' and 'Sub-stage' have been used by Jowett (1925) whereas, Ball (1877), Feistmantel (1882), Hughes (1885), Oldham (1893), have adopted the 'System' 'Series' 'Group' terminology. However, with the publication of the code of Stratigraphic Nomenclature of India (1971) much of the confusion has been eliminated.

Two schemes of nomenclature, namely, lithostratigraphic and time-stratigraphic, have been proposed in respect of the Gondwanas but none of these has been accorded general acceptance. Sen (1965), Bakshi (1967), Casshyap (1970), Sengupta (1970), Qidwai (1972), Khan (1978), Tewari (1980), Kumar (1984) and Rais (1985) have followed the lithologic-stratigraphic scheme while the time-stratigraphic (chrono-stratigraphic) scheme has been adopted by Krishnan (1949), Wadia (1939), Ghosh and Basu (1967). This situation is mainly due to the difficulty in correlation resulting from the wide variation of lithological and biological content, closed nature of the basins and great aereal distance of one basin from the other.

The lithostratigraphic scheme of classification has been adopted in this work. The time-stratigraphic terms like 'System', 'Series' and 'Stage' presently in usage have been replaced by lithostratigraphic terms such as 'Supergroup', 'Group', 'Formation' and 'Member'.

1.4. STRATIGRAPHY OF THE AREA

The Gondwana sediments of the Son-Mahanadi belt, of which the study area is a part, have been classified by Choudhury (1977, p. 787). A modified version of this classification is presented in Table 3. A gelogical map of the area appears as Figure 2 (cover pocket).

Table 3 : Gondwana Stratigraphy in the Study Area (modified from Choudhury, 1977).

Supra-Barakar Formation	Non-coal bearing
Barakar Formation	Coal-bearing
Disconformity (at places)	
Talchir Formation	Non-coal bearing
~~ Unconformity ~~~~	
Pre-Gondwana Formations	

1.4.1. Pre-Gondwana Formations

1.4.1.1. Archaean Rocks of Basinal Area

The basement rocks on which the Gondwana sediments actually rest in the study area comprise of granite and granite-gneiss of Archaean age. In the southern part of the area in the vicinity of Korba, the granites are coarse grained and often pass imperceptibly into a coarse grained, well-foliated, porphyritic biotite gneiss. North-west of this area, true granites are rare and are replaced by fine grained, well foliated granite gneiss.

The Archaean basement rocks occur continuously all along the edge of the Gondwana basin in this area. They also crop out extensively as long, narrow, big and small, NW-SE trending ridges from within the Talchir rocks indicating that the floor on which the Talchir sediments were deposited was highly uneven and traversed by long and high ridges running parallel to the general NW-SE trend of the main basin and consisting of granite-gneisses.

1.4.1.2. Archaean Rocks of Extra Basinal Area

A little distance from the western edge of the Gondwana basin, lying to the south, south-west and west of the area under investigation, cropout a variety of Archaean meta-sedimentary rocks occurring in patches. These are believed to belong to the 'Chilpi Series' and comprise of 'massive quartzite, quartz-schist, mica-schist and slate interbedded with greenstones and trappoid rocks (Wadia, 1939; Pascoe, 1965; Krishnan, 1968).

In the Sambhalpur-Raigarh-Sarangarh region, south and south_east of the present area, lie a series of highly metamorphosed rocks of the same age and comprise of garnetiferous gneiss, quartz-garnet schist, mica schist and quartzite.

1.4.1.3. Purana Rocks of Extra Basinal Area

The rocks of the great Chattisgarh basin of Purana age lying with a profound unconformity on the Archaean rocks, outcrop extensively to the south and southwest of the study area. The rocks are undisturbed, practically unmetamorphosed and comprise of a sequence of conglomerates, sandstones, shales and limestones. These rocks have been correlated with the Cuddapahs of South India by Wadia (1939, p. 118) and Pascoe (1965, p. 376) and with the Vindhyans by Krishnan (1968, p. 189).

1.4.2. Talchir Formation

The name 'Talchir Series' (hereinafter called the

Talchir Formation as per the Code of Stratigraphic Nomenclature of India, 1971) was given by W.T. Blanford, H.F. Blanford and W. Theobald (1856) after the earstwhile princely state of Talchir in Orissa, where the rocks were first described.

This Formation is the oldest in the Gondwana sequence and lies directly over the Archaean granites and gneisses, the junction between the two being profoundly unconformable (Plate-I, Figs. 1 & 2) in most cases or faulted at some localities (Plate-I, Fig. 3).

The rocks of this Formation are very different from the rest of the Gondwana formations in many respects. Green colour is very typical of all the lithounits constituting this Formation. However, the most characteristic and genetically important feature of the Talchirs is the presence of two diamictite units - one at the base resting on the Archaean basement and the other higher up in the sequence.

Basically seven lithofacies makeup the Talchir sequence in the study area. These are massive (basal) diamictite, stratified (upper) diamictite, mudstone with or without dropstone, massive sandstone, cross-stratified channel sandstone, interbedded shale and siltstone/sandstone and splintery shale. The massive diamictite unit is poorly sorted and contain clasts of different sizes, roundness, sphericity and lithology which float in an abundant quantity of clayey detrital matrix. The stratified diamictite is very similar to the massive diamictite but differs from it in its

EXPLANATION OF PLATE I

Figure 1 Massive diamictite at the base of Talchir sequence lying unconformably over fine grained foliated granite gneiss of Archaean age.

Note the near horizontal contact between the two.

Jhulna _nala_ section.

Figure 2 Massive diamictite at the base of Talchir sequence resting conformably over sheared, vertically foliated granite gneiss.

Note steep contact between the diamictite and gneiss.

Ambikapur Road section about 5 km from Marhai.

Figure 3 Faulted contact between Talchir sandstone (fore ground) and granite gneiss (back ground). The sandstone dip into the gneiss.

Hasdo river section, about 6 km from bridge on Ambikapur road.

Figure 4 Contact of cross-stratified Talchir sandstone with Barakar sandstone.

Note that horizontally disposed Barakar sandstone rests on very low dipping Talchirs indicating slight disconformity between the two.

Kharpari _nala_ section about 20 m upstream from road bridge.

PLATE I

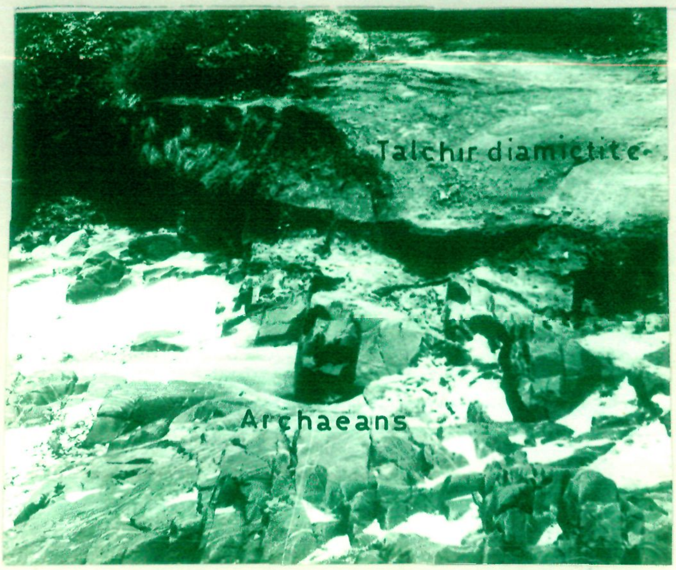

Fig.1

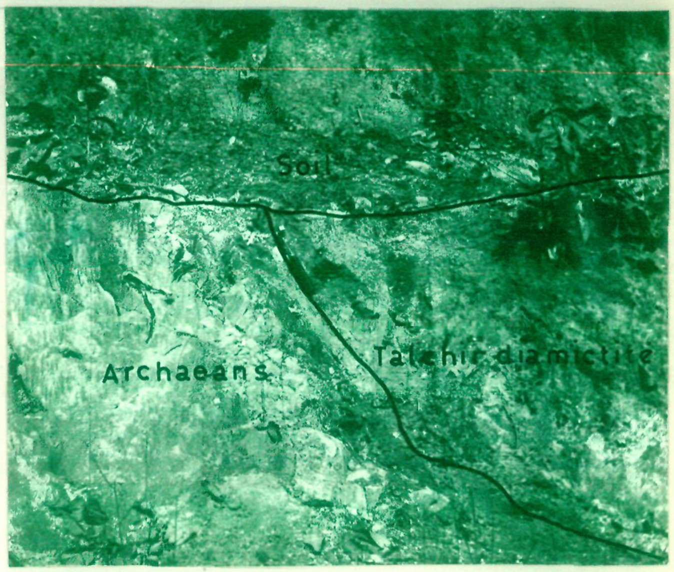

Fig.2

Fig.3

Fig.4

stratigraphic position, textural attributes of the enclosed clasts, lesser quantity and sandy nature of matrix and its crudely stratified structure. Occasionally, small lenses of fine grained cross-stratified sandstones occur within this unit. The three sandstone lithofacies are very similar to each other in their textural and compositional characters. They are all fine to very fine grained and range in composition from sub-litharenite to sub-arkose. The mudstones are massive units and often contain occasional dropstones. The shales are splintery bluish or blackish green in colour.

1.4.3. Barakar Formation

The rocks of the Barakar Formation in the study area rest on the Talchir rocks with a very slight angular unconformity at some places (Plate-I, Fig. 4) and often overlap on to the Archaean basement rocks. The former feature is clearly seen in the Kharpari nala section where the Talchir lithofacies are truncated against the Barakar rocks while an overlap relationship is obvious in the Kotri nala section about 7.5 kms west of Pali town (Fig. 2).

The Barakars comprise of grey coloured, coarse to medium grained, feldspathic sandstones which are thick-bedded and generally profusely cross-stratified. The sandstones are inter-bedded with micaceous sandy shales, carbonaceous shales and coal seams.

1.4.4. Supra-Barakar Formation

Rocks resting conformably on the Barakars, but devoid of coal, occur in a small patch in the eastern central part of the study area about 18 km north of Korba. They have been tentatively correlated with the Kamthi Formation of Godavari Valley (= Raniganj Formation of Damodar Valley) by Roy *et al.*, (1962).

The Supra-Barakar rocks form high flat topped geomorphic features. Lithologically they are very similar to the underlying Barakars and comprise of grey sandstones and conglomerates with intercalated shale bands.

1.5. STRUCTURE OF THE AREA

The structural nature of the Gondwana basins has been a matter of controversy ever since they were first studied. Blanford *et al.* (1856) and Oldham (1893) believed that the Gondwana coalfields occupy areas of depression which were further accentuated as deposition proceeded. Simpson and Ball (1922, p. 2) opined that the Gondwana coalfields represent 'basins of original deposition' at some places while at others they are preserved due to faulting. Greisbach (1880); Jowett (1925); Gee (1932, 1941), Ahmad (1960) and Krishnan (1968) have expressed the opinion that originally the Gondwana basins must have extended over larger tracts. Fox (1934, p. 23), on the other hand believes that these basins were block faulted and that the Gondwana sediments were deposited in these well defined structural basins. Wadia (1939, p. 166) also holds generally the same view but concedes that "some of the boundary faults may be of post-Gondwana age'. Pascoe (1959) seems entirely to agree with this view.

According to Chatterjee and Ghosh (1967), major faulting in the Gondwana basins started during the Barakar sedimentation and not earlier. In the opinion of Chaudhury (1977, p. 789) "the sedimentation attributes of Talchir Formation indicate the total absence of any tectonic imprint on the sedimentary framework of the basins and the 'a-tectonic' embryonic character of the area during Talchir deposition is well established". He further suggests that during the succeeding Damuda times, there was a complex role of tectonism within the basinal area.

CHAPTER-2

FACIES ANALYSIS

2.1. INTRODUCTION

Facies analysis of Talchir sediments in the study area is based on a careful examination of most of the accessible sections exposed in the area.

A complete section of the Talchir Formation is nowhere exposed in the study area (Casshyap and Srivastava, 1986). This is due to the fact that much of the area is thickly vegetated and covered by alluvium as a result of which it becomes difficult to get good and continuous exposures except in stream and river cuttings. Another important reason is that the Talchir Formation in the study area is overlain by the Barakar Formation with a slight unconformity thus covering large expanses of the Talchir rocks about which no information is available.

2.2. LITHOFACIES TYPES, TERMINOLOGY AND CODING

Three basic lithofacies are recognised in the area of study on the basis of grain size, bedding characters and sedimentary structures, namely, diamictite, sandstone and fine clastics and are coded by the capital letters, D, S, and F respectively using the modified scheme of Miall (1983). Each sub-type is also coded by using appropriate lower case letters (Casshyap and Srivastava, 1986). The main lithofacies and sub-facies are listed in Table-4.

The term 'diamictite' has been used in this study for a "lithified, poorly, sorted, clast-sand-mud admixture without consideration to its origin or environment of deposition" (Frakes, 1978; Eyles et al., 1983). This term, therefore, is non-genetic in contrast to a term like 'tillite' which has a genetic significance inasmuch as it indicates a glacial origin for the sediment concerned (Boulton, 1976).

Two diamictite units occur in the area - one at the base of the Talchir sequence, herein called the 'basal diamictite', and the other higher up in the sequence and termed as 'upper diamictite'.

2.3. DESCRIPTION OF SECTIONS

The sections examined in the study area are given below and are located in Figure-2.

1. Jhulna Nala Section
2. Tan Nadi (Road-bridge) - Gursian and Pondi-Bango Section.
3. Bansajhal - Lathgarh Nala Section

Table 4 : Lithofacies Types of Talchir Formation in the study area

Diamictite (D)	Poorly to moderately sorted clast-sand-mud admixture
Dm	Massive diamictite
Ds	Stratified diamictite
Sandstone (S)	Fine to medium grained locally pebbly,
Sp and St	Cross-stratified, planer and trough
Sm	Massive
Fine Clastics (F)	Mudstone, shale, siltstone, fine sandstone, locally carbonaceous, shale commonly inter-bedded.
Fl	Laminated mudstone, minor shale-siltstone with or without dropstones.
Fr	Ripple cross-laminated to laminated shale, siltstone/fine sandstone.
F-d	Splintery shale with or without dropstones.

4. Ambikapur Road - Hasdo River Section
5. Kharpari Nala Section
6. Hasdo River Section at Korbi.

2.3.1. Jhulna Nala Section

Jhulna _nala_ is a tributary of Ahiran Nadi which meets the main river Hasdo at Korba town. The Talchir Formation exposed in this section is not extensive, the total exposed thickness as recorded by the author being only about 14 meters.

The following lithofacies occur in this section.

2.3.1.1. Basal Diamictite (Dm)

The diamictite facies in the Jhulna _nala_ section lies unconformably on granitic gneiss (Plate-II, Fig. 1). It is about one meter thick, dirty brownish in colour, massive and polymictic in composition. The diamictite is poorly sorted and consists of a jumbled up mass of sub-angular to sub-rounded pebbles, cobbles and boulders, mostly of local derivation, embedded in a green, fine grained matrix.

The lithology of the clasts present in this facies is varied and consists of metamorphic, igneous and sedimentary rocks. The commonly present lithologic types are quartzite

EXPLANATION OF PLATE II

Figure 1	Massive (basal) diamictite (Dm) resting unconformably on gneiss. The diamictite is a jumbled up mass of boulders, cobbles and pebbles lying in an abundant fine grained matrix.
	Jhulna nala section, 2 km southwest of Rajkamma village.
Figure 2	Laminated mudstone facies (Fl) showing occasional dropstones.
	Note parallel and continuous laminations in this facies.
	Jhulna nala section about 10 m downstream from the outcrop shown in Figure 1..
Figure 3	Top of massive sandstone facies (Sm) showing plastering of clasts.
	Note high density of packing and moderate sorting of clasts.
	Jhulna nala section about 200 m from outcrop shown in Figure 2.
Figure 4	Cross-stratified sandstone facies (Sp and St) showing very low angle of foresets.
	Jhulna nala section further downstream from outcrop in Figure 3.

PLATE II

Fig. 1

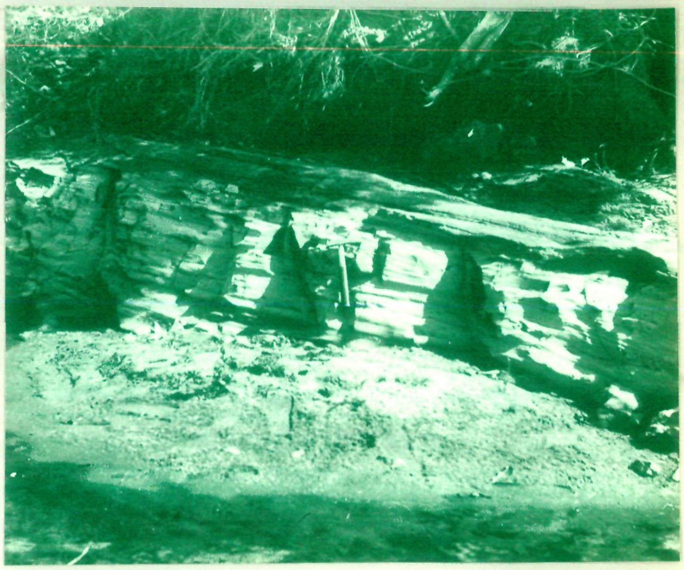

Fig. 2

Fig. 3

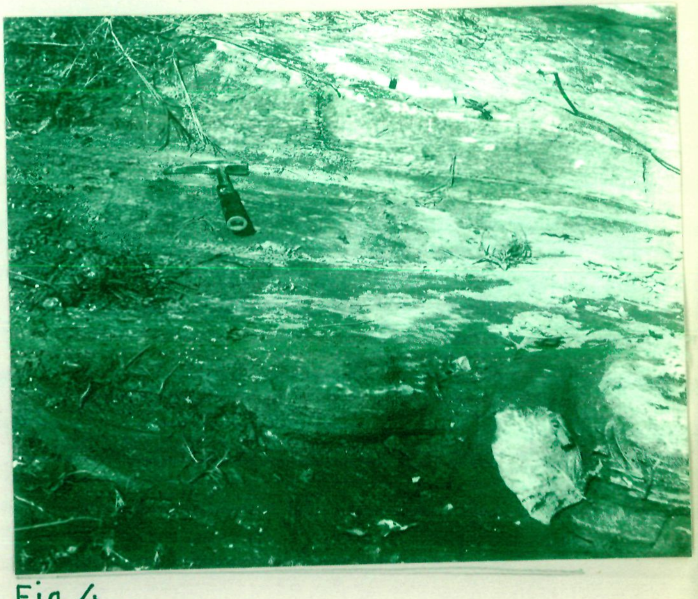

Fig. 4

(37%) followed by gneiss (22%), red coloured sandstone (21%), granite (10%), basalt (4%), greenstone and limestone (2% each) and chert and schist (1% each).

The basal diamictite facies is massive and does not show any structure of any type.

2.3.1.2. Mudstone with or without Dropstone (Fl)

The massive diamictite facies passes upwards into a laminated mudstone which contains a few scatter dropstones (Plate-II, Fig. 2). The contact between the two facies is gradational-intercalated. It is important to note that the colour, composition and texture of the green laminated mudstone is remarkably similar to the fine matrix of the diamictite suggesting the derivation of the former from the latter.

This facies is yellowish brown to greyish green in colour. Only about 2 meters of this facies is exposed in the Jhulna nala section.

The mudstone is thinly laminated and contains a small number of clasts sparsely scattered in the mudstone on their lower surface and are interpreted as dropstones. The clasts are of the same lithology and size as are seen in the underlying basal diamictite indicating that they have a common source.

An interesting feature of this facies is that it contains small lenses of siltstone which are ripple cross-laminated. The cross-laminations occur in isolated sets and are 2-3 cm. thick showing tangential foresets. As will be discussed later, these lenses indicate reworking of the material under the influence of weak currents.

2.3.1.3. Fine grained massive sandstone (Sm)

The fine grained massive sandstone in the Jhulna nala section rests over the laminated mudstone facies with a gradational contact. It is yellowish brown in colour and is very fine to medium grained. The vertical thickness of this facies exposed on the surface is about four meters.

In the upper part of this facies at some outcrops, the bedding surface of the sandstone shows a thin layer of densely packed, subrounded to rounded clasts of the same composition as are contained in the basal diamictite (Plate-II, Fig. 3). The clasts are polished and are coated with a shining layer of blackish colour.

Another interesting feature seen in the upper part of this facies is the occurrence of discontinuous isolated patches of splintery green shales in shallow, depressions in the sandstone. The shale lenses are 5 cm to 2 m thick and not more than 5 m across.

The occurrence of pebbly and fine clastic 'facies' in juxtaposition in the upper part of this facies appears to be of interest in so far as the depositional conditions at the close of the deposition of this facies are concerned. It is clear that at this point of time conditions existed where, on the one hand, strong currents deposited pebbles and cobbles and, on the other 'pools' of stagnant water existed where the fine clastics were deposited by suspension.

2.3.1.4. Fine grained cross-stratified sandstone (Sp and St)

This facies is yellowish brown to dirty green in colour and comprises fine grained sandstone showing low-angle cross-stratification (Plate-II, Fig. 4). It rests on the massive sandstone facies just described. In the lower part this facies occurs as big and small, planar cross-stratified channels in the underlying rocks. The width of these channels varies from less than 5 meters to more than 30 meters and their axes trend from 75^{o}-255^{o} to 93^{o}-273^{o}.

In the upper part of this facies, the channels coalesce and form continuous, medium grained, planer cross-stratified sandstone bodies. The foresets of cross-strata dip generally in the north-east direction.

This facies is overlain by coarse-grained Barakar sandstone.

2.3.2. Tan Nadi (Road Bridge) - Gursian and Pondi - Bango Sections

In Tan Nadi section, the rocks of Talchir Formation, exposed along the up and down-stream side of the bridge on Kathghora-Chirimiri road, rests unconformably on a striated granite pavement (Plate-III, Fig. 1). The striated pavement, reported by Ahmad et al. (1976), has crescentic marks which indicate the movement of ice towards northwest (304^{o}). The rocks of the Talchir Formation are deposited in this area in valleys in between Archaean ridges running approximately in the NW-SE direction.

The Talchir rocks exposed in this section are comparatively more extensive and thick than the previously described section. The total exposed thickness recorded in this section is about 44 meters.

2.3.2.1. Basal Diamictite (Dm)

About 5 meters thick, the basal diamictite rests unconformably on the striated Archaean rocks in the vicinity of Tan Nadi bridge. It is earthy grey to brownish green in colour, polymictic in composition and is poorly sorted.

The clasts of various lithologies, shape, and size are embedded in a green coloured clayey matrix. As far as

EXPLANATION OF PLATE III

Figure 1 Striated Archaean basement in the bed of Tan Nadi. Pen is placed parallel to striation.

About 700 m downstream from road bridge on Tan Nadi.

Figure 2 Slumpsed masses of shale and siltstone of overlying formation in the upper part of massive (basal) diamictite (Dm).

Left bank of Tan nadi about 720 m downstream from road bridge.

Figure 3 Inter-bedded shale-siltstone/fine sandstone facies (Fr) showing rhythmic alternations of shale and siltstone/fine sandstone.

About 800 m downstream from road bridge on Tan Nadi.

Figure 4 Symmetrical ripple marks on top of siltstone beds in the above facies.

Locality same as above.

PLATE III

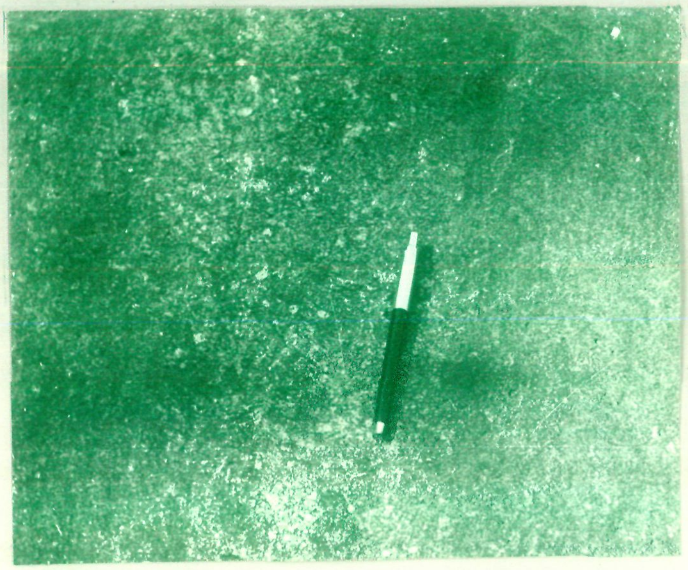

Fig. 1

Fig. 2

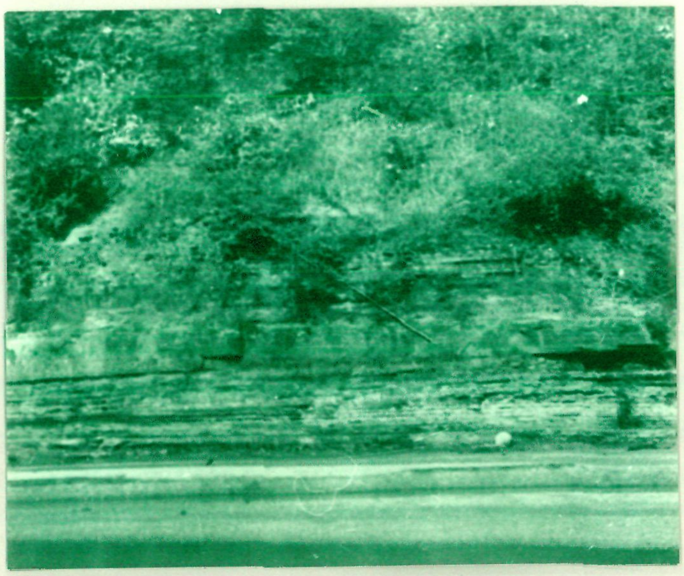

Fig. 3

Fig. 4

the lithology of the clasts is concerned, they are metamorphic, igneous and sedimentary rocks. The commonly present lithologic types are quartzite (about 37%), followed by granite (22%), sandstone (17%), gneiss and limestone (8% each), schist (4%), greenstone (3%) and slate (1%).

The clasts exhibit a wide range of roundness values from very angular to well rounded but the majority of the clasts are sub-angular to sub-rounded. They are of different sizes ranging from pebble to boulders but the majority of the clasts vary in size from 32-16 mm. The clasts present in this diamictite are about 8% of the rock by volume and are loosely packed.

A genetically significant and striking feature of the topmost portion of basal diamictite in this section is the occurrence of isolated huge blocks of slumped material, the biggest of them measuring roughly 65 meters by 7 meters on the left bank of Tan Nadi about 800 meters downstream from the road bridge. The slumped masses comprise of folded, contorted, twisted and often broken blocks of shale and siltstone of the overlying formation which lie scattered and churned up with the material of the diamictite (Plate-III, Fig. 2).

2.3.2.2. Interbedded shale and siltstone/fine sandstone (Fr)

The interbedded shale and siltstone/fine sandstone facies lying over the basal massive diamictite is brownish to greyish green in colour. This facies is exposed both in the Tan Nadi and Pondi-Bango sections. In the former section this facies is exposed along the depositional strike and hence does not give any idea of its thickness; in the latter section it outcrops along the dip direction and hence a fairly accurate idea of its thickness can be obtained. The exposed thickness of this facies has been estimated to be about 12 meters.

This facies comprises of sediments characterised by a rhythmic alternation of shale and siltstone/fine sandstone (Plate-III, Fig. 3). The shale units show thin parallel laminations and are greyish green to yellowish brown in colour. At few outcrops small lenses of limestones (150 x 7 cm) are also seen. The shale component is more in the lower portion of this facies and decreases towards the top.

The siltstone units are reddish to yellowish brown in colour and contain parallel bedded brownish coloured bands of calcareous material. Towards the top of this section, the thickness of the siltstone bands increases and small symmetrical ripple marks with SE-NW trending axes are present (Plate-III, Fig. 4). The top three feet of the sequence is marked by the appearance of fine grained, bedded sandstone, occurring as channels in the underlying rocks. The channels trend 140°-320°.

2.3.2.3. Laminated Mudstone with or without dropstones (Fl)

Laminated mudstone facies in the Tan Nadi and Pondi-Bango section is greyish green in colour and occurs in small patches. The vertical thickness of mudstone as exposed in the Tan Nadi section is about 7 meters and in the Pondi-Bango section is about 2 meters.

In Tan Nadi section the upper part of mudstone contains sub-angular to sub-rounded clasts of different sizes and lithology and constitute about 6% of the rock by volume (Plate-IV, Fig. 1). On the other hand, this facies in the Pondi-Bango section is thinly laminated and is devoid of clasts.

2.3.2.4. Fine grained, cross-stratified sandstone (Sp and St)

This facies overlies the mudstone facies in the Pondi-Bango section but is not exposed in the Tan Nadi (road bridge) - Gursian section, most probably being covered under the alluvium. The sandstone of this facies is greyish green in colour, fine grained and very compact.

In the lower part of this section, the sandstones occur as big and small, flat topped channels within the laminated mudstone, devoid of any cross-stratification (Plate-IV, Fig. 2). Higher up in the sequence the channels coalesce and form continuous bodies of planar and trough cross-stratified

EXPLANATION OF PLATE IV

Figure 1 Laminated mudstone facies (Fl) showing huge boulders occurring as dropstones.

About 200 m upstream from road bridge on Tan Nadi.

Figure 2 Cross-stratified sandstone facies (Sp and St) occurring as flat-topped channels in laminated mudstone (Fl).

About 350 m upstream from road bridge on Tan Nadi.

Figure 3 Splintery shale (F-d) showing massive character.

Pondi-Bango section, about 1 km southwest of Pondi village.

Figure 4 A boulder occurring as dropstone in the splintery shale (F-d).

Locality same as above.

PLATE IV

Fig. 1

Fig. 2

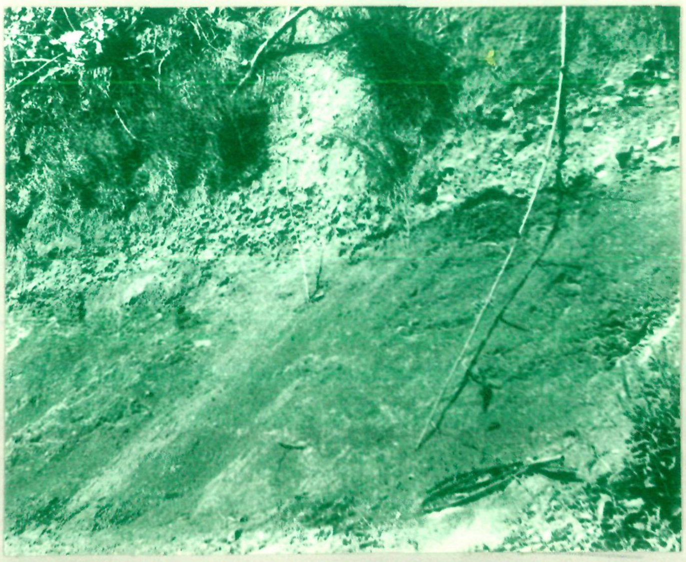

Fig. 3

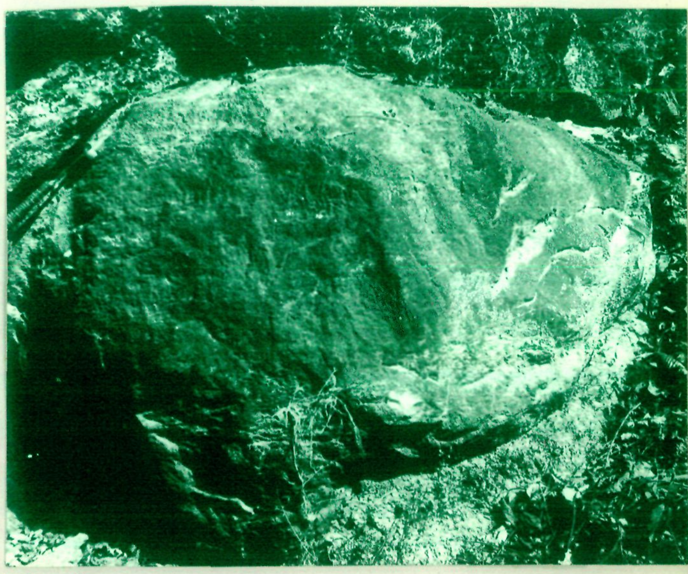

Fig. 4

sandstones. The planar type of cross-stratification is much more common than the trough type. However, the cross-stratification foresets in both types generally dip towards north-east direction.

The vertical thickness of this facies as exposed in the Pondi-Bango section is about 12 meters.

2.3.2.5. Splintery shale with or without dropstones (F-d)

The khaki green, splintery shale facies lies over the cross-stratified sandstone and is about 6 meters thick. It breaks into long thin splinters with a slight touch of the hammer.

The shale is generally massive but occasionally bedding is visible specially where small intercalations of siltstone are present (Plate-IV, Fig. 3). Occasional clasts as dropstones occur in this facies in the Pondi-Bango section. The clasts are more or less of the same lithology as present in the basal massive diamictite facies. (Plate-IV, Fig. 4).

2.3.3. Bansajhal Nala - Lathgarh Nala Section

The rocks of Talchir Formation in this section unconformably rests on the Archeans in the Bansajhal nala where the contact between the two is clearly seen.

The Talchir sequence in this section is comparatively better developed than in most previously described sections. The vertical thickness of the sequence as exposed on the surface is about 76 meters.

2.3.3.1. Basal Diamictite (Dm)

The basal massive diamictite facies in this section is exposed only in the vicinity of Bansajhal nala. This facies unconformably lies over the Archaean rocks. It is about 6 meters thick, dirty brown to greyish green in colour, poorly sorted and is heterogeneous in composition.

The clasts are embedded in clayey/silty matrix, loosely packed, sub-angular to sub-rounded and on an average 32 mm to 16 mm in size, although some big ones can also be seen (Plate-V, Fig. 1). The composition of the clasts is the same as at other localities where this facies is developed.

A genetically significant and striking feature of this diamictite facies seen in this section is the occurrence of isolated blocks of slumped material (as in Tan Nadi - Gursian section). The slumped masses comprise of folded, contorted, twisted and often broken blocks of shale and siltstone of the overlying formation which lie scattered and churned up with the material of the diamictite (Plate-V, Fig. 2).

EXPLANATION OF PLATE V

Figure 1 Massive (basal) diamictite facies (Dm) showing angular to sub-rounded clasts in a clayey/silty matrix.

Note poor sorting of the diamictite.

Bansajhal nala north of Jatga village.

Figure 2 Slumped masses of siltstone and shale in upper part of Dm similar to one seen in Tan Nadi section.

Locality same as above.

Figure 3 Inter-bedded shale-siltstone/fine sandstone facies (Fr).

Note rhythmic alternations of shale and siltstone.

Bansajhal nala north of Jatga village.

Figure 4 Symmetrical ripple marks in siltstones of facies Fr as above.

Locality same as above.

PLATE V

Fig.1

Fig.2

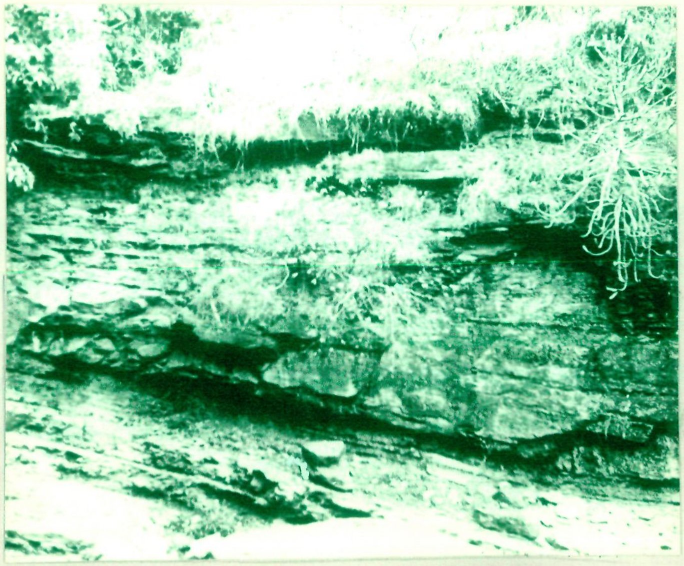

Fig.3

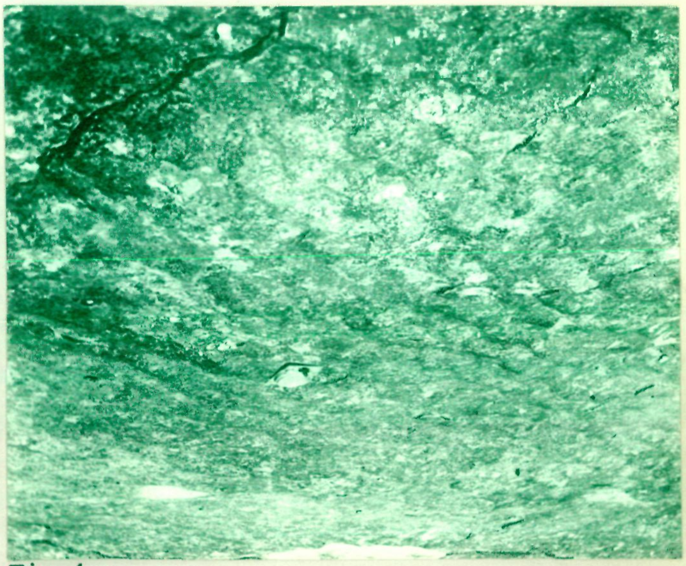

Fig.4

2.3.3.2. Interbedded shale and siltstone/fine sandstone (Fr)

The interbedded shale and siltstone/sandstone facies lies over the basal massive diamictite facies. It is about 17 meters thick and occurs in small and discontinuous patches rather than a continuation unit in the whole section (Plate-V, Fig. 3). It is brownish to greyish green in colour and comprises sediments characterized by rhythmic alternations of shale and siltstone/sandstone.

The shale unit is thinly parallel laminated and is greyish green in colour. In the lower part of the sequence, shales dominate over siltstone/sandstone while it is vice versa in the upper part.

The siltstone/sandstone units are reddish to yellowish brown in colour and contain bands of calcareous material. At few places small symmetrical ripple marks with SE-NW trending axes are present (Plate-V, Fig. 4). The thickness of siltstone beds increases towards the top. In the Bansajhal *nala* section the thickness of siltstone/sandstone is about 14 meters.

2.3.3.3. Fine grained massive sandstone (Sm)

The massive sandstone facies in this section rests over the interbedded shale and siltstone facies with a gradational contact. It is yellowish brown to greyish green in colour and is fine grained. The vertical thickness of this facies as exposed in this section is about 15 meters.

In the lower part of this facies, sub-angular to sub-rounded clasts of different sizes are sometimes present. The clasts are of the same composition as are present in the basal diamictite facies. The upper part of this facies is devoid of clasts.

2.3.3.4. Green splintery shale with or without dropstones (F-d)

This facies is exposed in all the localities of this section and varies in thickness from 2 meters to 28 meters. Best exposures are seen in the Kahwa nala (a small tributary of Bansajhal nala) where it is very extensively developed.

The shale facies is olive green in colour and is thinly parallel laminated. It is generally massive but occasionally bedding is visible specially where small intercalations of siltstone are present (Plate-VI, Fig. 1). Occasional clasts occur as dropstones in this facies in the Bansajhal nala section. The clasts are more or less of the same lithology as present in the basal massive diamictite facies in this section.

EXPLANATION OF PLATE VI

Figure 1 Splintery shale facies (F-d) showing massive character. Siltstone intercalations at base indicates bedding.

Note scattered dropstones in shales.

Kahwa nala, north of Jatga village.

Figure 2 Stratified (upper) diamictite (Ds).

Note small size of clasts and their high density of packing.

P.W.D. Rest House, Marhai.

Figure 3 Splintery shale facies (F-d) showing thin siltstone intercalations.

Lathgarh nala about 500m east of P.W.D. Rest House, Marhai.

Figure 4 Dropstone in splintery shale facies.

Note that clasts puncture the laminations in shales.

Lathgarh nala about 100 m east of P.W.D. Rest House, Marhai.

PLATE VI

Fig.1

Fig.2

Fig.3

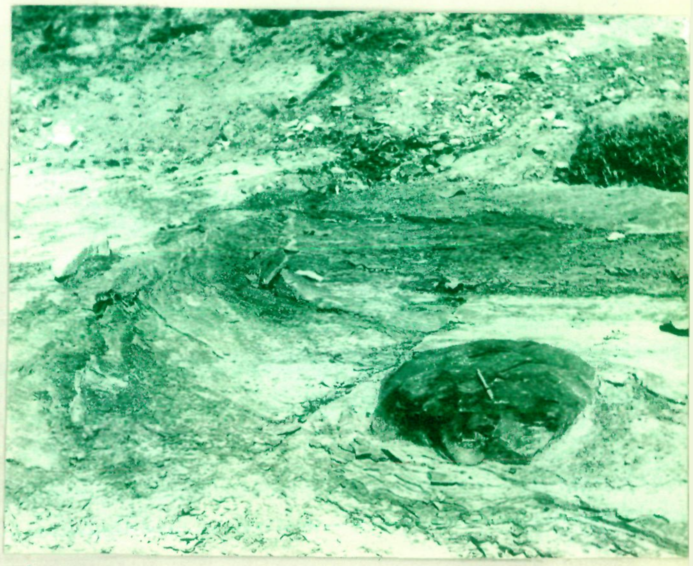

Fig.4

2.3.3.5. Upper Diamictite (Ds)

The upper diamictite facies in this section conformably lies over the facies just described. It is dirty brown to greyish green in colour and is about 5 meters thick as exposed on the surface.

Clasts of this diamictite unit are moderately to moderately well sorted and are embedded in a sandy matrix (Plate-VI, Fig.2). The commonly present clast lithologies are quartzite (43%) followed by sandstone (21%), granite (19%), gneiss (13%) and shale (about 5%). The clasts range from sub-angular to sub-rounded but the majority of the clasts are sub-rounded. They vary in size from 4 mm. to 128 mm. but majority of them are between 32-16 mm. in size. Clasts present in this diamictite facies are about 7% of the rock by volume.

2.3.3.6. Splintery shale with or without dropstones (F-d)

This facies is thinly laminated (Plate-VI, Fig. 3) and at few outcrops consists of clasts which puncture the laminations on their lower surface and may be termed as dropstones (Plate-VI, Fig. 4). The clasts are few in numbers, of different size and shape and comprise of lithologies identical to those occurring in the upper diamictite. This facies as exposed in this section is about 6 meters thick.

2.3.4. Ambikapur Road - Hasdo River Section

The sediments of Talchir Formation as exposed in this section, lie unconformably on the Archaean rocks (granitic gneiss) are much more extensive and thicker than the sections described earlier. They are very well exposed along the Kathghora - Ambikapur road cutting about 5 km north-east of Marhai and in the Hasdo river gorge. The total exposed thickness as recorded by the author is about 105 meters.

2.3.4.1. Basal Diamictite (Dm)

This facies is about 8 meters thick, greyish green in colour, polymictic in composition, poorly sorted and consists of a jumbled up mass of pebbles, cobbles and boulders in a greyish green paste like clay matrix (Plate-VII, Fig. 1).

This facies consists of clasts of quartzite (about 43%) followed by siltstone/sandstone (about 21%) granite (about 18%) gneiss (about 13%) and slate (about 5%). The clasts range from angular to well rounded but the majority of the clasts are sub-angular to sub-rounded. They are of different sizes ranging from pebble to boulders but the most common size lies in the coarse pebble grade (32-16 mm). The density of packing of clasts is about 7% of the rock by volume. This facies does not show any structure of any type and passes upwards into mudstone with or without clasts.

EXPLANATION OF PLATE VII

Figure 1 Outcrop of massive (basal) diamictite (Dm) showing poorly sorted debry in fine grained matrix. The big clast in the centre is that of quartzite.

5 km northeast of Marhai on Ambikapur road.

Figure 2 Outcrop of mudstone resting over basal diamictite.

20 m northeast of above outcrop.

Figure 3 Massive sandstone showing scattered clasts.

50 m towards Hasdo river on the same road.

Figure 4 Splintery shale showing thin laminations. Thin sandy lenses indicate bedding of the formation.

About 2 km east of outcrop no. 1.

PLATE VII


Fig. 1


Fig. 2


Fig. 3


Fig. 4

2.3.4.2. Mudstone with or without dropstones (Fl)

With the decrease in the packing density of clasts the basal diamictite passes gradationally into the mudstone with or without clasts facies (Plate-VII, Fig. 2).

This facies is about 6 meters thick as exposed in the Kathghora - Ambikapur road section. Sub-angular to sub-rounded clasts of different sizes occur sporadically (packing density less than 2% by volume)in the greyish green mudstone.

2.3.4.3. Fine grained massive sandstone (Sm)

The massive sandstone facies is about 20 meters thick and rests conformably over the mudstone facies. It is yellowish to greyish green in colour fine grained and is moderately sorted. No sedimentary structure is seen in this facies. However, occasional clasts may be seen here and there floating in the body of the massive sandstone (Plate-VII, Fig. 3).

2.3.4.4. Splintery Shale with or without dropstones (F-d)

The splintery shale facies as exposed in this section is about 32 meters thick and lies conformably over the massive sandstone facies. It is greenish to khaki green in colour and is by far the most characteristic type of rock of the Talchir

Formation. The shales of this facies are on the whole thinly laminated, the laminations being closely spaced, regular to uneven and moderately continuous in outcrops (Plate-VII, Fig. 4). In its uppermost part, this facies becomes silty and often contains small sandy lenses. The sandy lenses show small scale cross-laminations.

2.3.4.5. Upper Diamictite (Ds)

The upper diamictite facies is exposed in the Hasdo River gorge near the bridge on the Kathghora-Ambikapur road, and is about 4 meters thick in this section (Plate-VIII, Fig. 1) Crude but distinct bedding is observed in the upper diamictite. In its uppermost part, this facies exhibits large scale ripple-bedding (Plate-VIII, Fig. 2). Some sandy lenses, devoid of pebbles, also occur in this part of the sequence and show small scale tabular cross-stratification.

This facies is heterogeneous in composition. Pebbles, cobbles and boulders are sparsely distributed in a tough sandy matrix. The commonly present clast lithologies are quartzite (about 50%), followed by gneiss (about 18%), granite (about 15%), sandstone (about 11%), limestone (about 5%) and greenstone (about 1%).

The clasts are generally sub-rounded to rounded and show a wide range of clast size ranging from 4 mm to 256 mm.

EXPLANATION OF PLATE VIII

Figure 1 Outcrop of stratified (upper) diamictite showing crude but distinct stratification. The lower surface resting on splintery shales is loaded.

20 m downstream from Ambikapur road bridge on Hasdo river, left bank.

Figure 2 Upper part of stratified (upper) diamictite showing large scale ripple bedding.

Same as above.

Figure 3 Outcrop of lower part of cross-stratified sandstones showing parallel bedding.

About 600 m downstream from above outcrop in Hasdo river.

Figure 4 Large scale planer cross-stratification in the above facies.

Near the junction of Hasdo river and Lathgarh nala right bank.

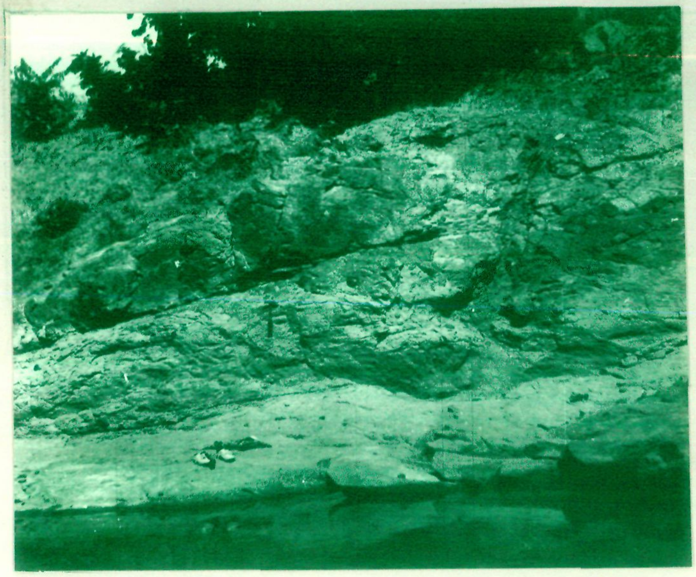

Fig. 1

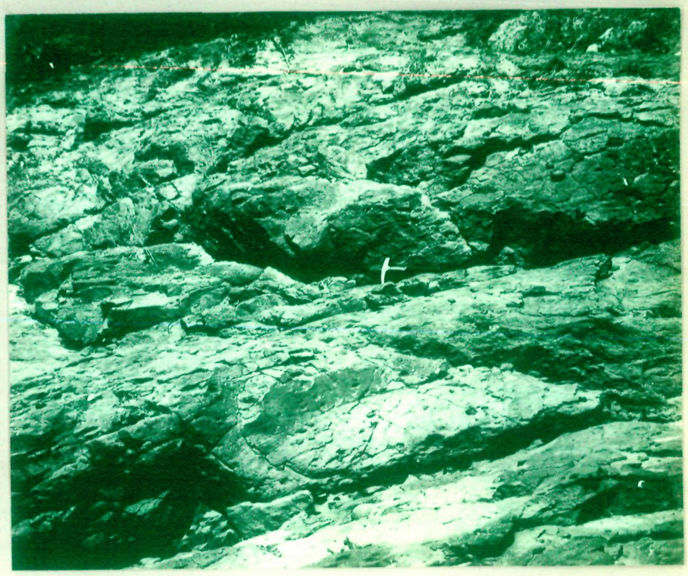

Fig. 2

Fig. 3

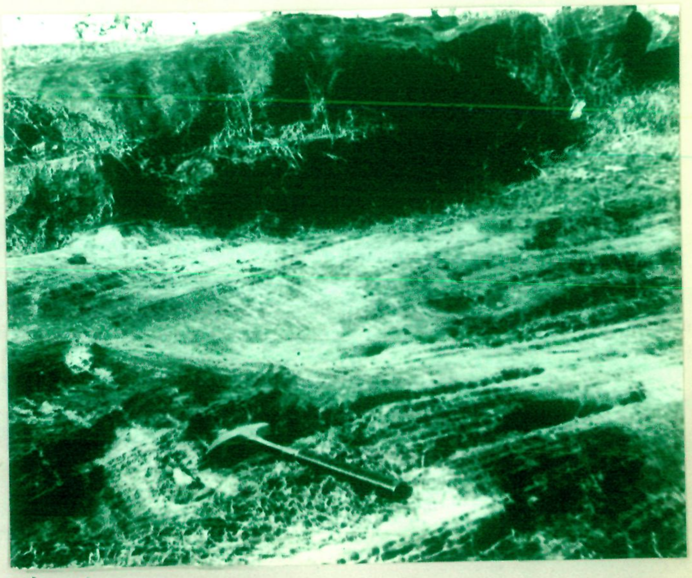

Fig. 4

2.3.4.6. Splintery shale with or without dropstones (F-d)

The stratified diamictite facies is overlain by green splintery shales which show remarkably the same characters as the underlying splintery shales. The characters of this facies are, therefore, not described here to avoid repetition. As a matter of fact, taken on a large scale, the stratified diamictite occurs as huge lenses within the splintery shale facies.

2.3.4.7. Cross-stratified sandstone (Sp and St)

Overlying the shales there is a development of cross-stratified sandstones about 20 meters thick which, in the bottom two meters, is parallel bedded (Plate-VIII, Fig. 3). Higher up in the sequence the sandstone is cross-stratified and occurs as big and small, sometimes coalescing, shallow channels (Plate-VIII, Fig. 4). The width of these channels varies from 7 to 80 meters and the channel axes are directed north-south. Planar cross-stratification is more abundant than trough cross-stratification. The foresets of cross-strata dip in the north-west direction.

This facies is succeeded by the Barakar sandstones.

2.3.5. Kharpari Nala Section

Only the upper part of Talchir Formation is exposed in a small section in the Kharpari nala, a small tributary of Hasdo river. The lower part of the sequence and the contact of this Formation with the underlying Archaeans is overlapped by the younger Barakar Formation and is therefore not exposed.

The Talchir rocks in this section are exposed in small and discontinuous patches and the total thickness as exposed in the area is about 25 meters.

2.3.5.1. Fine grained massive sandstone (Sm)

The fine grained massive sandstone facies is about 11 meters thick. It is greenish in colour, fine to very fine grained and is moderately sorted. In the topmost part of this facies, sub-rounded to rounded clasts are sporadically present.

2.3.5.2. Green splintery shale with or without dropstones (F-d)

The fine grained massive sandstone facies is overlain by 3 meters thick khaki green shale similar to the splintery shale facies described earlier.

The shale is thinly laminated, the laminae being closely spaced, regular to uneven and moderately continuous in outcrops. Dark green laminated shales occur towards the top of this facies in this section.

2.3.5.3. Upper Diamictite (Ds)

The upper diamictite facies in the Kharpari nala section is about 2.5 meters thick. It is greyish green in colour and moderately sorted.

The clasts embedded in the sandy matrix are loosely packed and comprise of quartzite (about 55%), followed by sandstone (16%), gneiss (15%), granite (11%) and limestone (2%). The clasts are of different sizes ranging from 0.6 mm to 128 mm (average size ranges between 32 mm and 16 mm) and are sub-angular to sub-rounded.

The upper diamictite facies is overlain by greenish, fine grained, cross-stratified sandstone facies.

2.3.5.4. Fine grained cross-stratified sandstone (Sp and St)

The cross-stratified sandstone facies is the topmost exposed facies in this section. The vertical thickness of this facies to the extent it is exposed, is about 7 meters.

It is fine grained, moderately to well sorted and shows profuse development of cosets of planar and trough cross-stratifications, the former is more widely developed than the latter (Plate-IX, Fig. 1). The foresets of cross-strata dip generally in the NW direction.

This facies is unconformably overlain by Barakar sandstone.

2.3.6. Hasdo River section at Korbi

The rocks of Talchir Formation are exposed within the Hasdo river gorge up and downstream of the temporary bridge on the Kathghora-Chirimiri road. In this section the contact of the underlying Archeans is covered with alluvium and river sand and is, therefore, not seen but its contact with the overlying Barakar Formation is clearly seen. The Talchir rocks exposed in this section are about 37 meters thick.

2.3.6.1. Fine grained massive sandstone (Sm)

The exposed thickness of this sandstone facies in the Hasdo river section at Korbi is about 11 meters. The sandstone is moderately sorted, fine grained and is characteristically olive green in colour.

At some places, this sandstone facies consists of a small number of sub-angular to sub-rounded clasts, scattered in the

EXPLANATION OF PLATE IX

Figure 1 — Large scale planar and trough cross-stratification in sandstones of Kharpari _nala_. The foresets are very long and gently inclined.

About 30 m downstream from the Chirimiri road bridge on Kharpari _nala_.

Figure 2 — Slumped massed of folded blocks of shales and silt-stones in splintery shale.

Note random orientation of these blocks.

About 50 m upstream from temporary road bridge on Hasdo river in Korbi village.

Figure 3 — Fine grained sandstones inter-bedded with stratified (upper) diamictite.

About 450 m upstream from the above location.

Figure 4 — Outcrop of fine grained cross-stratified sandstone showing very low angle planer cross-stratification.

Further upstream in Hasdo river at Korbi.

PLATE IX

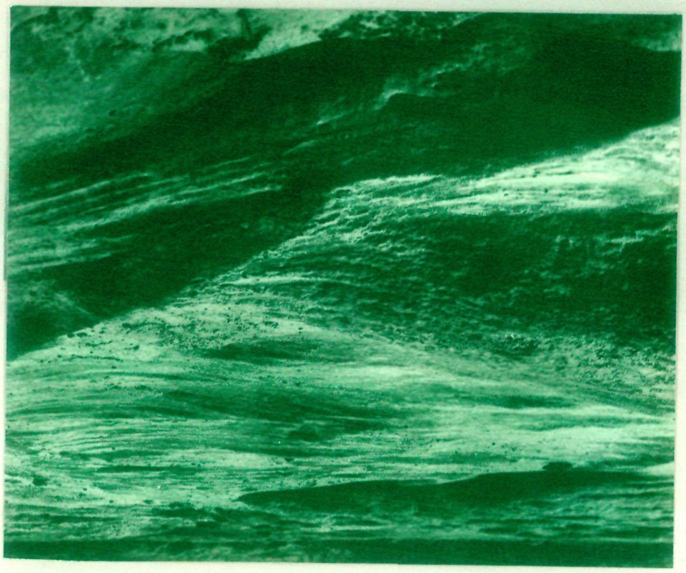

Fig. 1

Fig. 2

Fig. 3

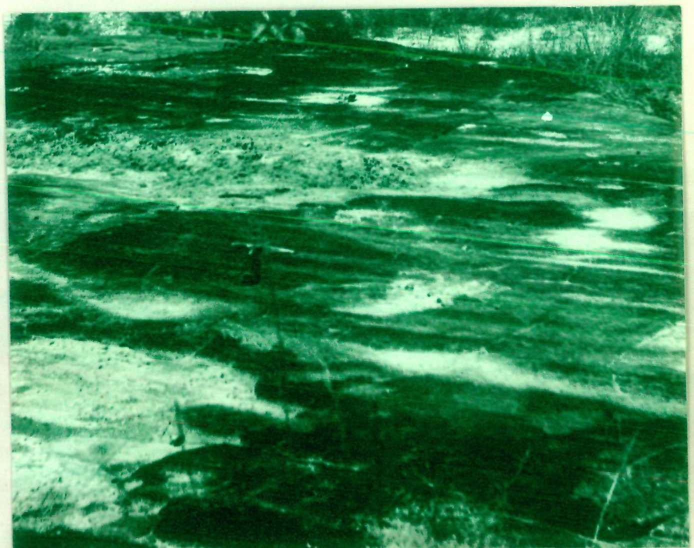

Fig. 4

body of the rock and are of the same lithology and size as in the upper diamictite facies occurring in this section. At others the percentage of these clasts increases to such an extent that this facies passes into pebbly sandstone. However, such outcrops are small and this pebbly sandstone can not be given the status of an independent facies.

2.3.6.2. Splintery shale with or without dropstones (F-d)

The splintery shale facies conformably lying over the massive sandstone facies is khaki to olive green in colour and is similar to needle or splintery shale facies as described in the earlier sections. This facies is thinly parallel laminated and is about 20 meters thick as exposed in the Hasdo river section at Korbi and contains some sandstone lenses at few places. Sub-angular to sub-rounded clasts of small and big size occur sparsely distributed in the shales. They puncture the shale laminae and are interpreted as dropstones.

A striking and genetically significant feature of this facies in this section is the occurrence of slumped masses of folded, contorted, and often broken blocks of shale, siltstone, limestone and mudstone which lie scattered in this facies (Plate-IX, Fig. 2).

2.3.6.3. Upper Diamictite (Ds)

About 3 meters thick, the upper diamictite facies conformably lies over the splintery shales, in the Hasdo river gorge at Korbi. This facies is greyish green in colour, moderately sorted and is heterogeneous in composition. At some places it shows crude stratification and is inter-bedded with fine grained sandstones (Plate-IX, Fig. 3).

Clasts of various lithology, shape and size are embedded in a greyish green coloured, sandy matrix. The commonly present lithologic types are quartzite (about 55%) followed by sandstone (16%), gneiss (15%), granite (11%), limestone (2%) and greenstone (about 1%). The clasts exhibit a wide range of roundness values from angular to well rounded but the majority of the clasts are sub-angular to sub-rounded. Similarly, they are of different sizes, the average size being inbetween 32 mm to 16 mm. The clasts present in this diamictite facies are about 4% of the rock by volume and they are loosely packed.

2.3.6.4. Fine grained cross-stratified sandstone (Sp and St)

This facies overlies the upper diamictite facies, just described in the Hasdo river section at Korbi and is about 6 meters thick. The sandstones are greyish green to yellowish green in colour, and medium to fine grained. The contact of this facies with the underlying diamictite facies is sharp.

Generally the sandstones of this facies occur in the form of big and small channels in shale facies. The width of these channels vary from outcrop to outcrop from about 4 meters to as much as 28 meters. The channel axes trend generally in the NE-SW direction.

The sandstones show planar and trough type of cross-stratifications, the planer type of cross-stratification being more common (Plate-IX, Fig. 4). The cross-stratification foresets generally dip towards the north-west direction.

The vertical thickness of this facies as exposed is about 6 meters.

2.4. SYNTHESIS

Table 5 summarises the vertical distribution of facies occurring in the Talchir Formation in the six sections studied. In all the sections where the Talchir rocks are seen to rest unconformably on the basement Archaean rocks, the sequence invariably starts with a basal diamictite unit which in turn passes upwards either into a mudstone facies containing drop-stones or an inter-bedded shale and siltstone/sandstone facies which also often contains dropstones. These pass upwards into a massive sandstone which, in a way, is a 'marker horizon'

Table 5 : *Vertical Distribution of Talchir Facies in the study area.*

Jhulna Nala Section	Tan Nadi-Pondi-Bango Section	Bansajhal-Lathgarh Nala Section	Ambikapur Road-Hasdo River Section	Kharpari Nala Section	Hasdo River Section at Korbi
			Barakar		
			Cross-stratified sandstone (20 m)	Barakar	Barakar
Barakar		Splintery shale with or without *dropstones* (6 m)	Splintery shale with or without *dropstones* (15 m)	Cross-stratified *sandstone* (7 m)	Cross-stratified *sandstone* (6 m)
Splintery shale with or without dropstones (2 m)	Splintery shale with or without dropstones (6 m)	Upper Diamictite (5 m)	Upper Diamictite (4 m)	Upper Diamictite (2.5 m)	Upper Diamictite (3 m)
Cross-stratified sandstone (5 m)	Cross-stratified sandstone (9 m)	Splintery shale with or without dropstones (28 m)	Splintery shale with or without dropstones (32 m)	Splintery shale with or without dropstones (4 m)	Splintery shale with or without dropstones (20 m)
Fine grained massive sandstone (4 m)	Fine grained massive sandstone (3 m)	Fine grained massive sandstone (15 m)	Fine grained massive sandstone (20 m)	Fine grained massive sandstone (11 m)	Fine grained massive sandstone (11 m)
Mudstone with or without dropstones (2 m)	Laminated mudstone with or without dropstones (7 m)	Inter-bedded shale and siltstone/ sandstone (17 m)	Mudstone with or without dropstones (6 m)		
	Inter-bedded shale and siltstone/ sandstone (12 m)				
Basal Diamictite (1 m)	Basal Diamictite (5 m)	Basal Diamictite (6 m)	Basal Diamictite (8 m)		
Archaean	Archaean	Archaean	Archaean		

inasmuch as this facies is developed in all the sections exposed in the area.

In localities in the immediate vicinity of the basin margin, for example in the Jhulna nala and Tan Nadi sections, the massive sandstone passes upwards into cross-stratified sandstone and then finally into a shale sequence. However, in areas away from the basin margin, the cross-stratified sandstone is not developed and the massive sandstone passes directly into splintery shale. The upper diamictite unit is seen only in such sections resting on the splintery shales. This second diamictite horizon passes upwards into cross-stratified sandstone and than finally into Barakar sandstone.

It is also noteworthy that the total thickness of Talchir Formation is small in areas at or near the margin of the basin and considerably thicker in sections in the deeper part of the basin. Thus, there appears to be a direct correlation between the geographical location of the section measured in relation to the basin margin and the total thickness of the lithounits developed. On this basis the six sections studied can be grouped into two types.

Type I : Facies developed in the proximal part of the basin. Total thickness of the section is small. Examples : Jhulna nala and Tan Nadi sections.

Type II : Facies developed in the distal part of the basin. The thickness of the section is much greater than in Type I. Examples : Ambikapur Road Section and Bansajhal-Lathgarh *nala* sections.

The remaining two sections are incomplete as their base is not exposed but looking at their close resemblance to the upper part of the sections of Type II, it can be inferred that they also belong to the same type.

As is evident from the geological map of the area (Fig. 2). Talchir rocks have been generally deposited between sub-parallel Archaean ridges running in the northwest-southeast direction. In each sub-basin coarser grained facies occur near the south-western margins which fine grained facies are developed near the northeastern end.

CHAPTER - 3

PETROGRAPHY

3.1. GENERAL REMARKS

The Talchir sequence in the study area comprises of a thick pile of sediments comprising diamictites, sandstones and shales. The diamictite lithostratigraphic units are volumetrically insignificant but the characteristics displayed by them are unique and mark them out as most interesting units in the entire Talchir sequence. The sandstones are, generally speaking, homogeneous in textural composition but show interesting features in regard to cementation. Shales do not exhibit much variation throughout the area and are least interesting from the point of view of petrography.

Both the units of the Talchir Diamictite comprise of material which exhibits a very large range of particle size and composition. To facilitate the study of these units, particles larger than 4 mm are considered in this study as forming the 'coarse fraction' and have been studied in respect of their mechanical composition, roundness, shape and lithology, Particles smaller than 4 mm have been regarded as constituting the 'fine fraction' of the diamictite and has been studied under the microscope in respect of particle size, roundness, and composition.

The sandstones of the area have been studied in respect of mechanical composition, roundness characteristics and composition.

Heavy minerals were extracted from the fine fractions of the diamictite units as well as from sandstones. The heavies from all the above lithounits are remarkably similar qualitatively and quantitatively. The percentage composition from each unit has been separately recorded to bring out this fact but to avoid repetition, the description of the individual species has been given only when describing the heavies of the fine fraction of the basal diamictite. Likewise only one Plate illustrating the characters of the heavy mineral grains has been introduced because grains from all lithounits are remarkably similar.

It is believed that the study of the fundamental textural and compositional attributes of the diamictites and sandstones would go a long way in understanding the sedimentation history of the Talchir sequence in this part of the country and in deciphering the nature and composition of provenance which supplied the sediments to the Gondwana basin.

3.2. METHODOLOGY

3.2.1. Mechanical Analysis

The various lithological units show widely divergent grain size distribution and, therefore, different methods had to be used for determining the nature of their size frequency distribution. The highly compact nature of the various lithounits precluded any possibility of using the customary 'sieve analysis'.

The coarse fraction of the diamictite comprising of clasts larger than 4 mm in size were treated separately for their size characteristics. Each suitable outcrop was divided into a grid pattern 1 m x 1 m size and all clasts within the grid were carefully dug out from the matrix. The long axis of each clast was accurately measured with the help of a wooden sliding gauge and data recorded using Wentworth scale. The lithology of each clast was also recorded in the field in order to study the relationship between clast size and clast lithology.

The fine fraction of the diamictite and the sandstones were subjected to thin section size analysis because all attempts to disaggregate them were futile due to their highly indurated/cemented nature. The apparent long axes of 300 clastic grains in each thin section were measured with the help of micrometer eye-piece. Care was taken to select only those grains in which effect of pressure solution and/or replacement by cement were absent or present only marginally. In order to obtain reasonably valid results Chayes (1949) point counting technique was employed.

Grain diameter measurements in millimeter were converted to Ø scale with the help of the conversion table compiled by Page (1955). The grain size data of each sample was grouped in half-phi classes and represented as histograms. Cumulative frequency curves were plotted on the graph constructed by Friedman (1958) which permitted the determination of sieve equivalents of the various percentiles. Statistical parameters described by Folk and Ward (1957) and Folk (1968, p. 44-48) were calculated for each sample.

3.2.2. Roundness Studies

Although it is known since long that the edges of clastic particles are modified during transport and that they get rounded with prolonged abrasion it was Wentworth (1919, 1922) who for the first time devised a quantitative method for measurement of this property. His 'roundness ratio' is defined as ri/R where 'ri' is the radius of curvature of the sharpest edge and 'R' the mean radius of the particle. It is to be noted, however, that Wentworth did not distinguish clearly between the shape and roundness of particles, which are two different and independent variables.

Wadell (1932) clearly distinguished and defined these two fundamental attributes of clastic particles. While roundness deals with the sharpness of the edges and corners, shape refers to their form. Roundness, as defined by Wadell (1932), is the ratio of the average radius of curvature of the edges and corners of the grain image projected to a standard size of 70 millimeters and the radius of the maximum inscribed circle. This method, though most accurate yet devised, is very slow and impracticable where many large samples are to be handled.

Russell and Taylor (1937) proposed five grade terms to express the roundness of particles and the class limits for these were fixed in accordance with the Wadell method, arithmetic means being used as class mid-points. Particles were assigned to classes on the basis of comparison with photographs of standard grains. However, this method cannot be applied to larger particles unless the photographs are enlarged to the appropriate size.

Krumbein (1941) devised a much quicker method of estimation of roundness of large clastic particles by visual comparison with nine silhouettes with roundness values ranging from 0.1 to 0.9, the silhouettes having being drawn from clasts whose roundness had already being determined by the Wadell method. The method of estimation consists of holding the clast in such a way that its maximum surface area is visible to the observer and then comparing it with the silhouettes. The clast is then assigned a roundness value. In this way a sample of hundred clasts can be handled in a short time with considerable accuracy.

Cailleux (1947) defined roundness as the ratio of the diameter of the sharpest corner in the plane of maximum projection and the longest axis of particle. Van Andel and others (1954) compared the methods of Cailleux and Wadell-Krumbein and have shown that the roundness values determined by the two methods are closely related. They further concluded that the Cailleux method was more time consuming and that the data obtained by the Krumbein method provide more detailed and more pertinent information than that obtained by the Cailleux method.

The roundness grades proposed by Pettijohn (1949) differ from those of Russell and Taylor (1937) in two important respects. Firstly, Pettijohn adopted a geometric scale in fixing the class limits and this brings about a clearer distinction between particles having low roundness values. Secondly, particles are assigned to appropriate classes by comparison with silhouettes and not photographs, making comparisons easier and more accurate. This method is very suitable for sand sized particles and modifications are necessary if it is to be used for larger particles.

Powers (1953) defined six roundness classes and published a visual comparison chart consisting of photographs of clay models grouping particles into classes. His scale is geometric and is useful where fine distinctions are required specially in the study of medium and fine grained clastics.

In the present study Krumbein's (1941, p. 68) roundness chart has been used for the visual estimation of roundness of clasts because this method is quick and large silhouettes are available for direct comparisons. Since the data had to be used primarily for determining the roundness characteristics of clasts of the two horizons of the diamictite a more accurate but time consuming method was not used.

The roundness of grains in sandstones and in the fine fraction of the diamictites was determined using the method given by Pettijohn (1975) as this method is simple, quick and sufficiently accurate. Care was taken to select only those thin sections in which the boundaries of the derital grains were clear and in which the effect of pressure solution was negligible. In order to have a uniform coverage of the thin sections, Chayes (1949) point counting technique was employed and the roundness of 300 grains in each section was estimated and tabulated. The arithmetic mean roundness of each sample was computed by the method given in Krumbein and Pettijohn (1938).

3.2.3. Shape Characteristics

Shape as distinct from roundness is an important property of clastic particles. Although to a large extent, the ultimate shape of clasts is inherited and in part controlled by structures it may also under the influence of certain modes of transport such as glacial, be considerably modified during dispersal. The presence of characteristic forms, even in a small number of particles in a deposit, may throw considerable light on its origin.

The opinion that clasts tend to develop characteristic shape when transported by certain transporting agencies (specially glaciers) has been expressed by many workers (Mansfield, 1907; Gregory, 1915; Twenhofel, 1926; Coleman, 1926; Von Engelen, 1930; Wentworth, 1936a, 1936b; Holmes, 1960; Srivastava, 1961, 1967; Charlesworth, 1966; Drake, 1968, 1970; Flint, 1971; Boulton, 1975; Ahmad, 1981). However, the forms outlined by the above workers are qualitative and, therefore, cannot be used either for comparison or for correlation purposes.

A more qualitative approach was made by Wadell (1932) who evaluated shapes of sedimentary particles in terms of their sphericity. He defined sphericity as the ratio of the surface area of a sphere having the same volume as the particle and the total surface area of the clast itself. In order to overcome the difficulties in the measurement of surface areas of irregular particles Wadell (1934, 1935) expressed sphericity as $\frac{dn}{Ds}$, where dn is the nominal diameter (diameter of a sphere having the same volume as the clast) and Ds the diameter of the circumscribing sphere (usually the largest axis of the clast).

Wadell's method, though very accurate, is time consuming and impracticable where large samples are to be handled. Further, the sphericity values obtained by this method do not give any idea of the actual shape of particles. Such a distinction was made by Zingg (1935, p. 54) who used the ratio of the longest (a), the intermediate (b), and the shortest (c) diameters of particles to define four shape classes namely, oblate spheroid (discoidal), spherical (equiaxial), bladed (triaxial) and the prolate spheroid (rod-like).

Krumbein (1941) has shown that a definite relationship exists between the three diameters of a particle as defined above and Wadell's sphericity indices, and has been able in this way to superimpose curves of equal sphericity on Zingg's chart. The discrepancy in Wadell's method therefore, can be overcome by using sphericity graphs. An additional advantage in using this method is that Zingg percentages can be directly obtained which constitute a useful information with respect to the shapes of particles.

Sneed and Folk (1958) introduced the concept of 'maximum projection sphericity' and devised a triangular diagram for analysis of different shapes (termed 'forms') of particles. In this method the long (L), the intermediate (I) and the short (S) axes are measured in such a way that the three axes, though not necessarily intersecting at the same point, are mutually perpendicular. The value of sphericity is read from a triangular graph by plotting the two diameter ratios S/L and $\frac{L-I}{L-S}$ and interpolating the position of the plot between lines of equal sphericity. This method has the "advantage of predicting the actual behaviour of particles during transport whether the transport be by suspension or by traction" (Sneed and Folk, 1958, p. 123). The form classes defined by these authors have a distinct advantage over those defined by Zingg (1935) inasmuch as the former defined 10 form classes while later defines only 4 form classes which are not really adequate for detailed investigations. Further, the classes defined by Zingg are very unequal and divide the field of variation into disproportionate compartments.

In the present study the method of Sneed and Folk (1958) has been used. The arithmetic mean has been used as a measure of average and standard deviation as the degree of scatter about the mean. These statistical parameters have been calculated as suggested by Krumbein and Pettijohn (1938).

3.2.4. Clast Lithology/Modal Composition

The clasts of the diamictites on which roundness and shape studies were made have also been used for the purpose of lithological studies. Most of the clasts were identifiable in the hand specimen but those which could not be so identified were subjected to microscopic study after preparing thin sections. Each sample was subjected to this process and the clast count were recorded. Since the long axis of each clast had already been recorded, the clast lithologies were classified according to size so that the relationship between clast size and clast composition could be studied.

The modal composition of the matrix of the diamictite units and that of sandstones was determined under the microscope using a Swift automatic point counter. 300 grains were counted in each thin section.

3.2.5. Heavy Minerals

As mentioned earlier the matrix of the diamictites as well as the different types of sandstones in the Talchir sequence in the area of study are highly indurated and/or cemented and therefore not amenable to disaggregation. The samples were crushed to fine size in an iron mortar. The crushed sample was sieved and 100 to 200 gms of the fraction finer than 120 mesh but coarser than 100 mesh were used for heavy mineral separation according to the method outlined by Krumbein and Pettijohn (1938) using bromoform of specific gravity 2.87 as the separating liquid. The heavy mineral crop was washed with alcohol, dried, weighed and mounted permanently in Canada balsam.

3.3. BASAL DIAMICTITE

3.3.1. Mechanical Composition of Coarse Fraction

Since the basal diamictite is best exposed in the Jhulna nala and Tan Nadi sections and the section exposed on the Ambikapur road, only these three areas were considered for the study of mechanical composition of the basal diamictite. A total of 1593 clasts were measured spread over ten outcrops as indicated below.

	Jhulna Nala			Tan Nadi			Road Section Ambikapur Road				Total
Outcrop No.	1	2	3	1	2	3	1	2	3	4	10
Number of clasts measured	143	167	140	219	195	189	117	119	147	157	1593

The results of the mechanical analysis at the various outcrops appear in Table 6. Histograms showing the size frequency distribution of the coarse fraction of the basal diamictite appear in Figure 3.

It is seen that the size frequency distribution of the clasts is unimodal in all samples studied. The diamictite is coarsest in the Jhulna Nala outcrops inasmuch as the modal

Table 6 : Mechanical composition of coarse fraction of the Basal Diamictite (Percentage by number)

Class (mm)	Jhulna Nala			Tan Nadi			Road Section Ambikapur Road			
	1	2	3	1	2	3	1	2	3	4
>256	11.18	1.79	0.71	0.45	-	-	-	-	-	-
256-128	20.97	10.77	11.42	6.84	2.56	-	-	1.36	0.63	1.70
128-64	25.17	25.74	28.57	15.52	6.66	4.76	4.20	4.08	7.00	0.85
64-32	22.37	34.73	30.71	19.63	28.20	24.33	26.89	29.25	35.03	27.35
32-16	18.88	23.35	22.14	28.31	32.82	34.39	31.93	34.69	36.30	29.05
16-8	1.39	3.59	6.42	22.83	21.02	24.86	28.57	23.12	17.19	20.51
8-4	-	-	-	6.39	8.71	11.64	8.40	7.48	3.82	20.51

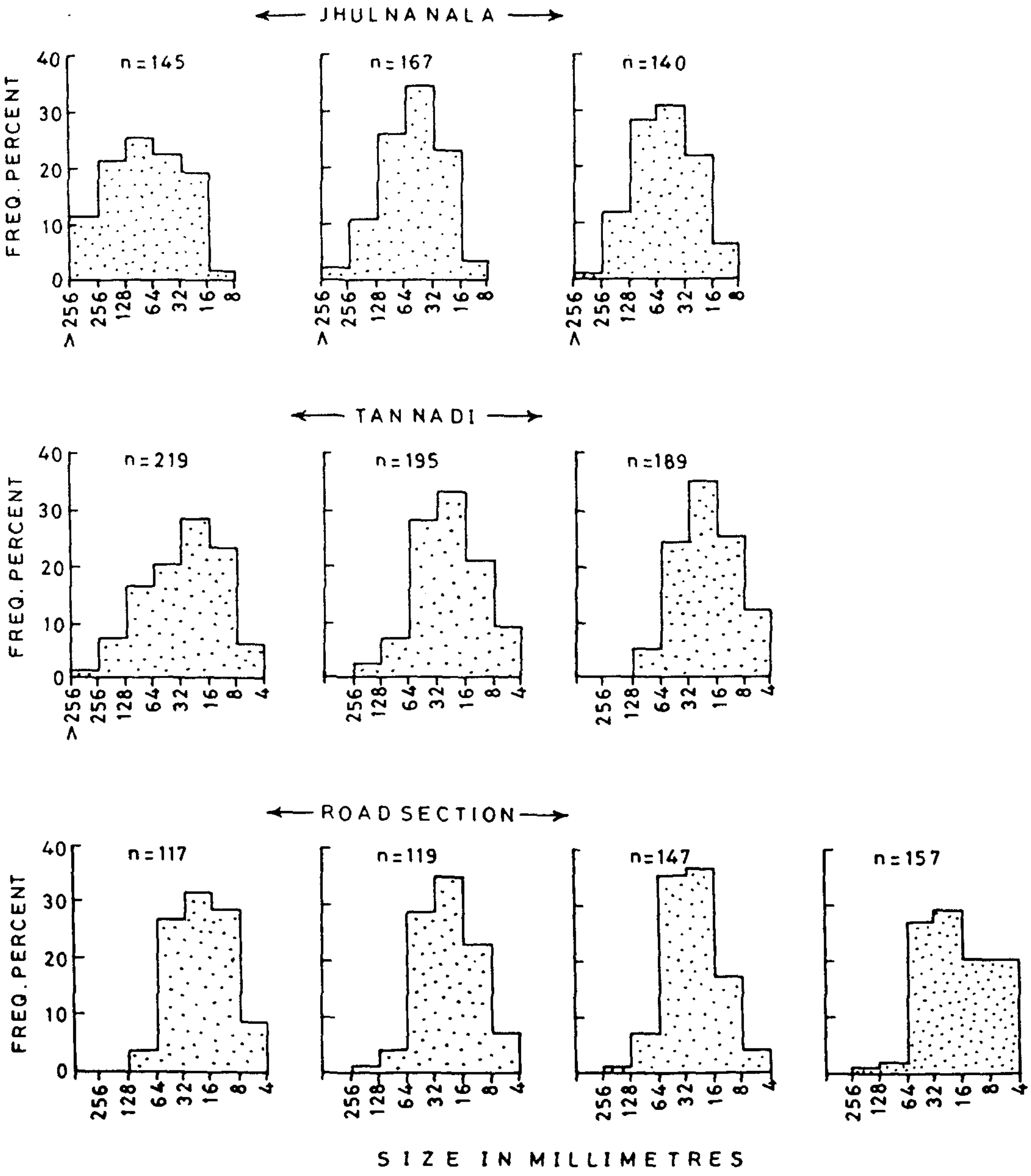

FIG. 3. HISTOGRAMS SHOWING THE SIZE FREQUENCY DISTRIBUTION OF COARSE FRACTION OF BASAL DIAMICTITE.

class lies in the 128-64 mm class in one sample and in the 64-32 mm class in the remaining two samples. However, both in the Tan Nadi and the section along the road leading to Ambikapur, the modal class lies uniformly in the 32-16 mm class. The spread of the data as indicated by the number of classes containing more than 5% of the material is 4 to 5 in the Jhulna nala section, 4 to 6 in the Tan Nadi section and 4 in the Ambikapur road section. There is, therefore, no significant difference in spread of the data at the various outcrops.

In 6 samples out of 10, the size frequency distribution is coarse skewed while in 4 it is fine skewed. The amount of material present in the modal class ranges from 25% to 36% and, therefore, the peakedness of the frequency distribution is moderate to low in the various samples.

3.3.2. Mechanical Composition of Fine Fraction

For reasons discussed under 3.3.1., the fine fraction of basal diamictite was investigated for the nature of its mechanical composition in three areas, namely, Jhulna nála, Tan Nadi and along the Ambikapur road. In the hand specimen as well as under the microscope, the nature of the fine fraction throughout the area appears to be very uniform. It is for this reason that only three thin sections, one from each area, were studied for grain size analysis.

Table 7 shows the results of thin section size analysis in the above mentioned areas and Figure 4 shows the size frequency distribution as histograms and cumulative curves. In contrast to the size frequency distribution of clasts, the fine fraction of the basal diamictite is bimodal in all samples studied. In the Jhulna nala the primary mode lies in the 3.0-3.5 Ø class (very fine sand) while in the Tan Nadi and Ambikapur road sections, it lies in the 3.5 to 4.0 Ø (very fine sand) and 4.0 to 4.5 Ø (coarse silt) class respectively. Likewise the position of the secondary mode is also variable and lies in the 4.5 to 5.0 Ø (coarse silt) class in Jhulna nala, in 3.5 to 4.0 Ø (very fine sand) class in Tan Nadi and in the 3.0-3.5 Ø (very fine sand) class in the Ambikapur road section. The spread of the data as indicated by the number of classes containing more than 5% of the material is 7 in the Jhulna nala and Tan Nadi sections and 6 in the section along the road to Ambikapur.

Table 8 shows the characteristics of the size frequency distribution of the fine fraction of the basal diamictite. The data show that the graphic mean size in all classes lies in the very fine sand grade and all samples are moderately sorted. With the exception of the sample from road section which shows near symmetrical size distribution, samples from Jhulna nala and Tan Nadi are fine skewed. All samples are mesokurtic.

Table 7 : Mechanical Composition of fine fraction of Basal Diamictite.

Size Class		Jhulna Nala		Tan Nadi		Road Section (Ambikapur Road)	
mm scale	Ø scale	Frequency Per cent	Cumulative Per cent	Frequency Per cent	Cumulative Per cent	Frequency Per cent	Cumulative Per cent
1.0-0.71	0.0-0.5	-	-	-	-	-	-
0.71-0.50	0.5-1.0	-	-	1.666	1.666	0.999	0.999
0.50-0.35	1.0-1.5	0.999	0.999	2.000	3.666	0.333	1.332
0.35-0.25	1.5-2.0	2.666	3.665	6.000	9.666	1.000	2.332
0.25-0.177	2.0-2.5	6.666	10.331	12.333	21.999	6.666	8.998
0.177-0.125	2.5-3.0	12.333	22.664	23.000	44.999	16.000	24.998
0.125-0.088	3.0-3.5	21.000	43.664	16.000	60.999	20.000	44.998
0.088-0.062	3.5-4.0	10.666	54.324	17.666	78.665	19.000	63.998
0.062-0.044	4.0-4.5	18.333	72.657	13.333	91.995	21.333	85.331
0.044-0.031	4.5-5.0	21.666	94.323	6.666	98.669	13.666	98.997
0.031-0.015	5.0-5.5	5.666	99.980	1.333	99.990	1.000	99.990
<0.015	5.5-6.0	-	-	-	-	-	-

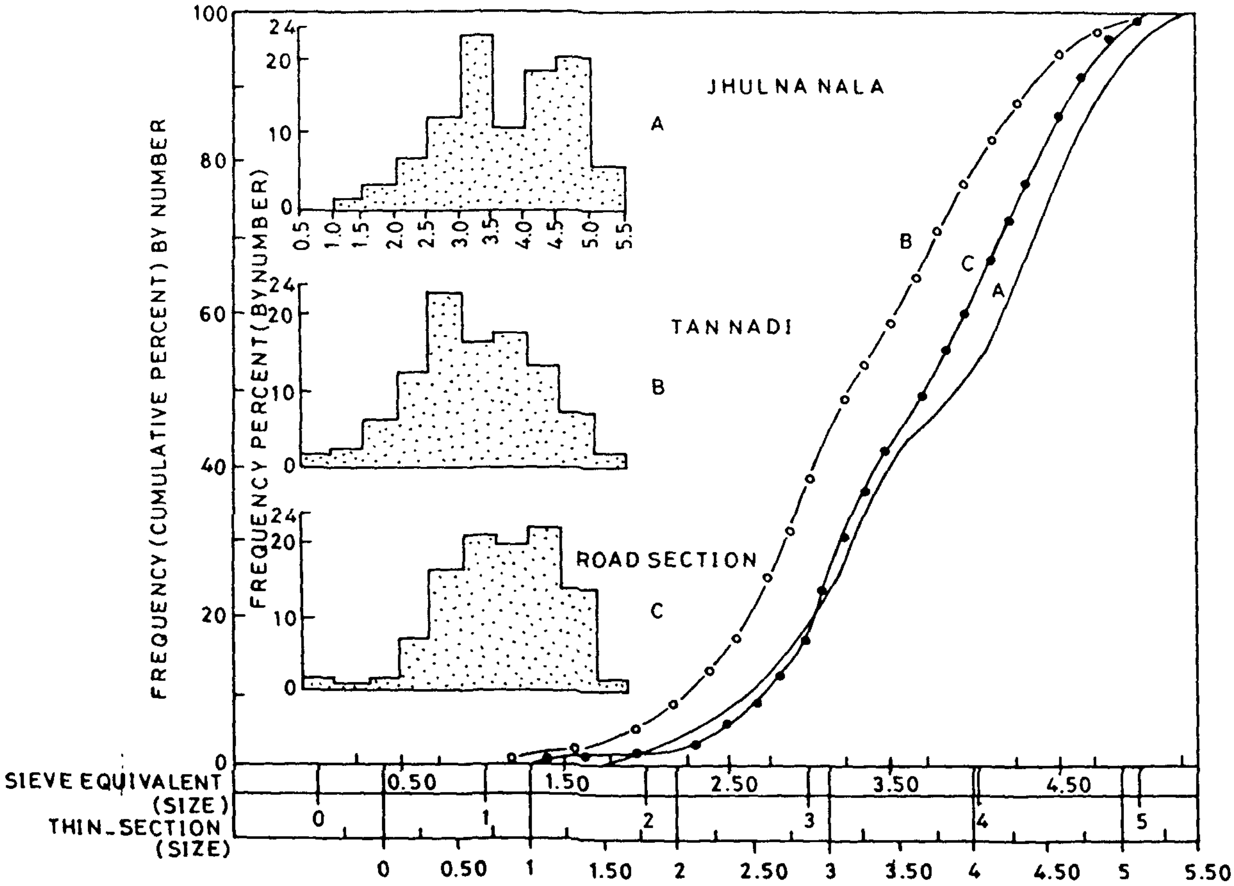

FIG. 4. HISTOGRAMS AND CUMULATIVE CURVES SHOWING SIZE FREQUENCY DISTRIBUTION OF FINE FRACTION OF BASAL DIAMICTITE.

Table 8 : Statistical Characteristics of size frequency distribution of fine fraction of Basal Diamictite.

Locality	Graphic Mean (Mz)	Inclusive Graphic standard deviation (σ_1)	Inclusive Graphic Skewness (SKI)	Graphic Kurtosis (KG)	Uni/Poly modal
Jhulna Nala	3.83	0.856 (Moderately sorted)	0.093 (Fine skewed)	0.908 (Meso-kurtic)	Bi-modal
Tan Nadi	3.326	0.866 (Moderately sorted)	0.093 (Fine skewed)	0.982 (Meso-kurtic)	Bi-modal
Road Section (Ambikapur Road)	3.676	0.738 (Moderately sorted)	-0.075 (Near symmetrical)	0.917 (Meso-kurtic)	Bi-modal
Average	3.61	0.836 (Moderately sorted)	0.025 (Fine skewed)	0.935 (Meso-kurtic)	Bi-modal

3.3.3. Roundness Characteristics of Coarse Fraction

A total of 522 clasts from various outcrops in the three main localities of the area (namely Jhulna nala, Tan Nadi and Ambikapur road) were studied for their roundness characteristics (Table 9). Figure 5(A) shows the frequency distribution of roundness values of clasts as histograms. In the Jhulna nala over 70% of clasts are sub-rounded and their arithmetic mean roundness is 0.337, which value lies slightly to the right of the mid-point of the sub-rounded class (0.315). In contrast, the clasts in the Tan Nadi section are more angular (Ma = 0.269) although the modal class lies in the sub-rounded class. The frequency distribution is clearly skewed towards lower roundness values and the peakedness of the frequency distribution is low. The roundness characteristics of clasts in the Ambikapur road section lies in between those described above. The modal class contains about 55% of the values and lies in the sub-rounded class.

Histograms representing the average frequency distribution of roundness values of clasts from all the three localities shows that more than 55% of clasts are sub-rounded and the arithmetic mean roundness is 0.306.

It is concluded that the clasts of the basal diamictite are generally sub-rounded and the frequency distribution in most cases is slightly skewed towards lower roundness values.

Table 9 : Roundness statistics of clasts in Basal Diamictite.

Roundness Class	Jhulna Nala (n = 203)			Tan Nadi (n = 151)			Road Section (n = 168)			Average (n = 522)		
	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)
Angular 0.00–0.15	2.95			18.54			11.30			10.15		
Sub-Angular 0.15–0.25	11.33			32.45			20.83			20.49		
		0.337	0.137		0.269	0.117		0.303	0.134		0.306	0.131
Sub-rounded 0.25–0.40	71.42			34.43			55.35			55.55		
Rounded 0.40–0.60	9.35			14.56			8.92			10.72		
Well-rounded 0.60–1.00	4.92			-			3.57			3.06		

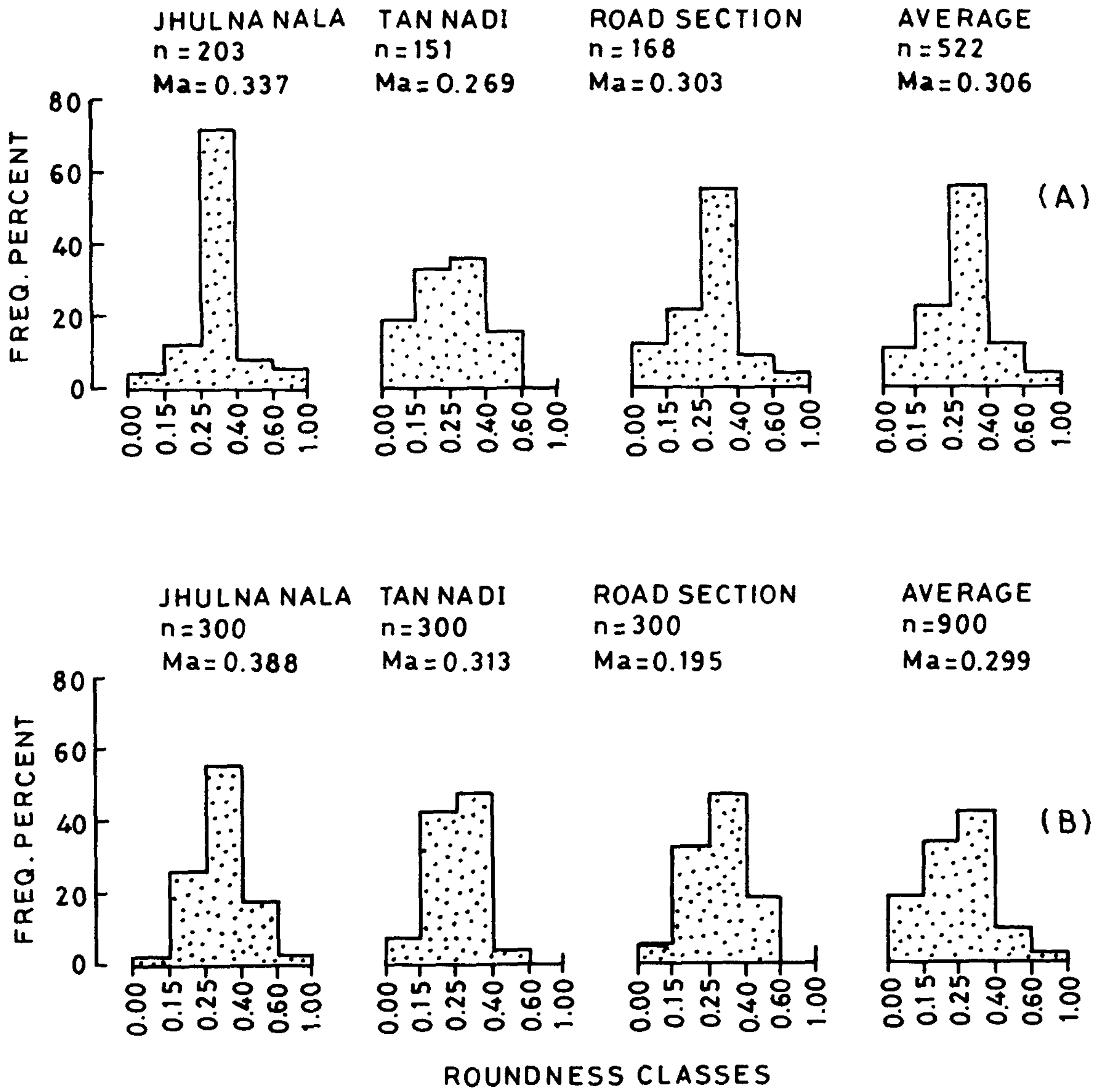

FIG. 5. HISTOGRAMS SHOWING THE DISTRIBUTION OF ROUNDNESS VALUES OF
(A). CLASTS EMBEDDED IN BASAL DIAMICTITE.
(B). GRAINS COMPRISING FINE FRACTION OF BASAL DIAMICTITE.

3.3.4. Roundness Characteristics of Fine Fraction

Table 10 shows the frequency distribution of roundness values of grains comprising the fine fraction of basal diamictite studied in thin sections from samples coming from the same localities for which clast roundness was studied.

Figure 5(B) graphically represents the roundness data as histograms. In the Jhulna nala and Tan Nadi sections the modal roundness class lies in the 0.25 to 0.40 (sub-rounded) class while in the road section the mode lies in the sub-angular class. 3 to 4 roundness classes contain more than 95% of the data and thus the dispersion of the data is small to moderate. The roundness frequency distribution is skewed towards angular grains and the peakedness is significant.

3.3.5. Shape and Sphericity of Clasts

292 clasts from the basal diamictite taken from outcrops in three localities of the area were subjected to an analysis of their shape and sphericity. The data are shown on triangular plots (Figs. 6A, 7A & 8A) following the method suggested by Sneed and Folk (1958, p. 123).

Table 11 summarises the shape characteristics of clasts in the Jhulna nala, Tan Nadi and Ambikapur road section. The most abundant shape of clasts of basal diamictite is compact bladed(CB). Their frequency percentage varying from 27.15 to 36.70 (average 32.19). Bladed (B) forms constitute the next in order of abundance (range 13.92 to 18.54, average 16.43)

Table 10 : Roundness statistics of fine fraction of Basal Diamictite.

Roundness Class		Jhulna Nala (n = 300)			Tan Nadi (n = 300)			Road Section (n = 300)			Average (n = 900)		
		Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)
Angular	0.00–0.15	1.33			6.66			47.66			18.55		
Sub-angular	0.15–0.25	25.33			41.66			31.33			32.77		
			0.388	0.130		0.313	0.117		0.195	0.138		0.299	0.151
Sub-rounded	0.25–0.40	55.33			47.66			18.33			40.44		
Rounded	0.40–0.60	17.66			4.00			2.66			8.11		
Well-rounded	0.60–1.00	0.33			-			-			0.11		

Table 11 : Shape Characteristics of Clasts in the Basal Diamictite.

Clast Form	Frequency (per cent) Jhulna Nala n = 79	Tan Nadi n = 151	Road Section n = 62	Average n = 292
Compact	12.65	12.58	4.83	10.95
Compact Platy	8.86	13.24	12.90	11.98
Compact Bladed	36.70	27.15	38.70	32.19
Compact Elongated	16.45	16.55	9.67	15.06
Platy	3.79	7.94	4.83	6.16
Bladed	13.92	18.54	14.51	16.43
Elongated	5.06	2.64	9.67	4.79
Very Platy	1.26	0.66	1.61	1.02
Very Bladed	-	-	3.22	0.68
Very Elongated	1.26	0.66	-	0.68

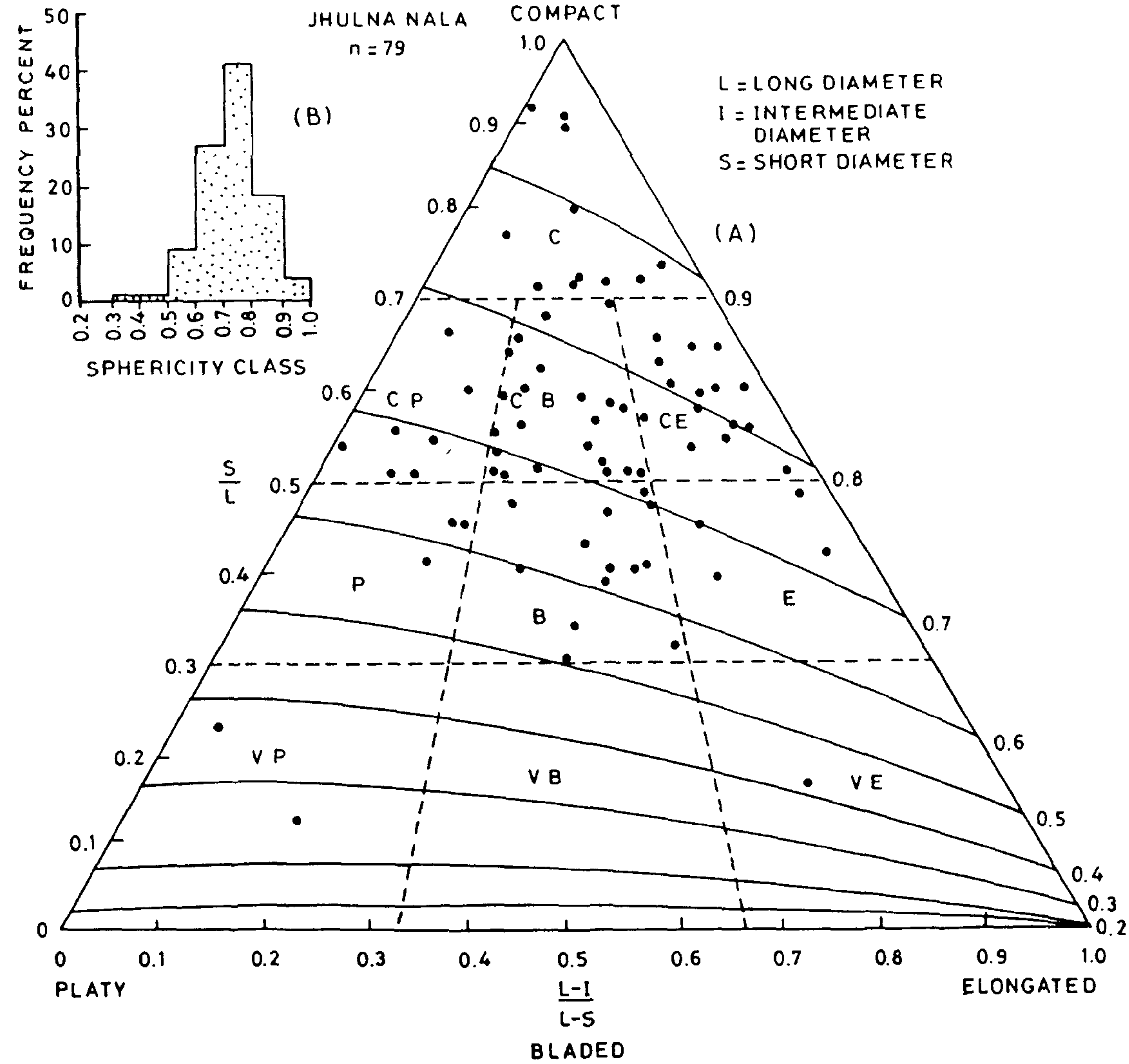

FIG. 6.(A) TRIANGULAR PLOT FOR SHAPE ANALYSIS OF CLASTS IN BASAL DIAMICTITE IN JHULNA NALA SECTION.
(B) HISTOGRAM SHOWING FREQUENCY DISTRIBUTION OF CLAST SPHERICITY FOR SAMPLE PLOTTED IN A.

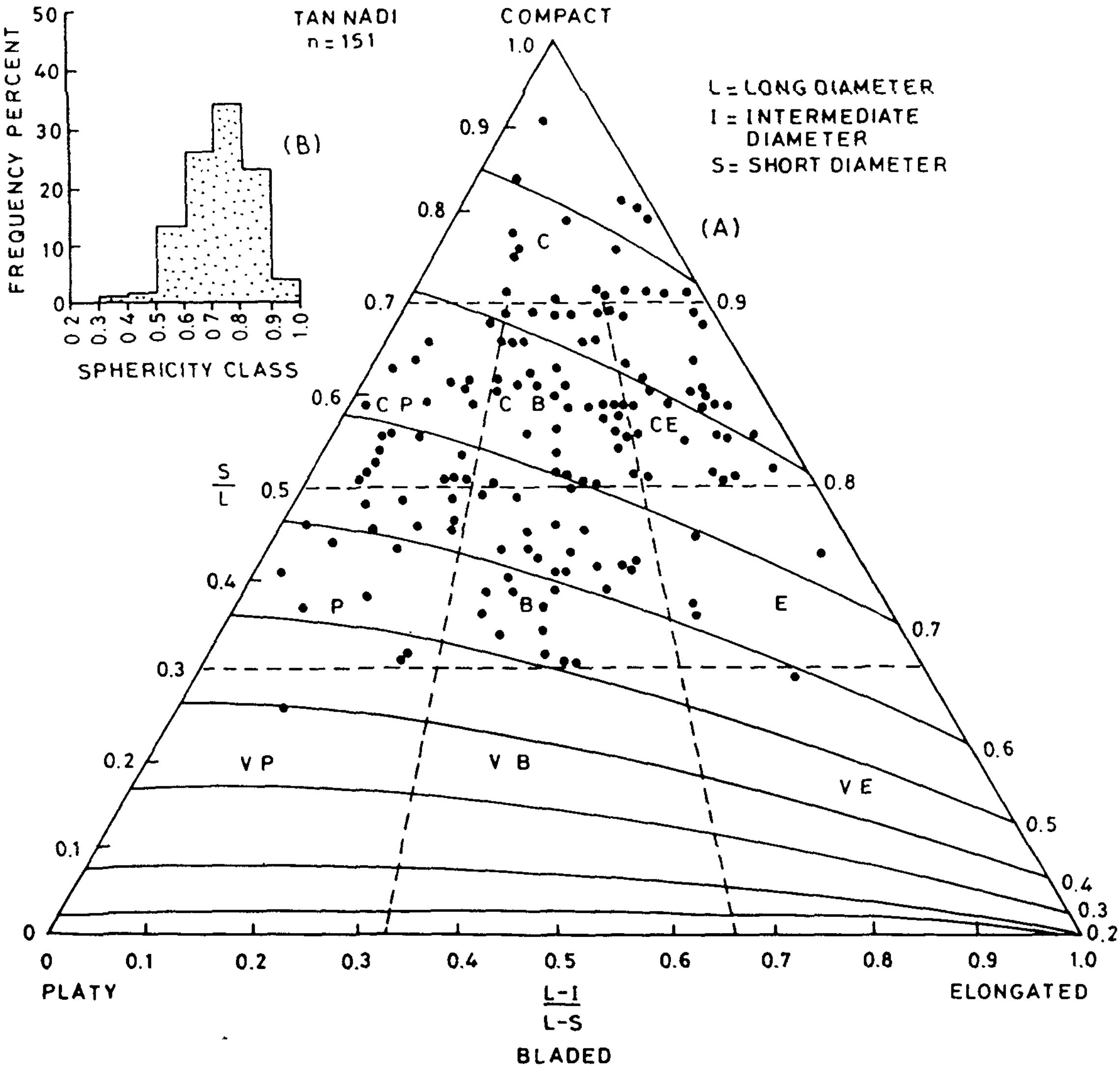

FIG. 7 .(A) TRIANGULAR PLOT FOR SHAPE ANALYSIS OF CLASTS IN BASAL DIAMICTITE IN TAN NADI SECTION.
(B) HISTOGRAM SHOWING FREQUENCY DISTRIBUTION OF CLAST SPHERICITY FOR SAMPLE PLOTTED IN A.

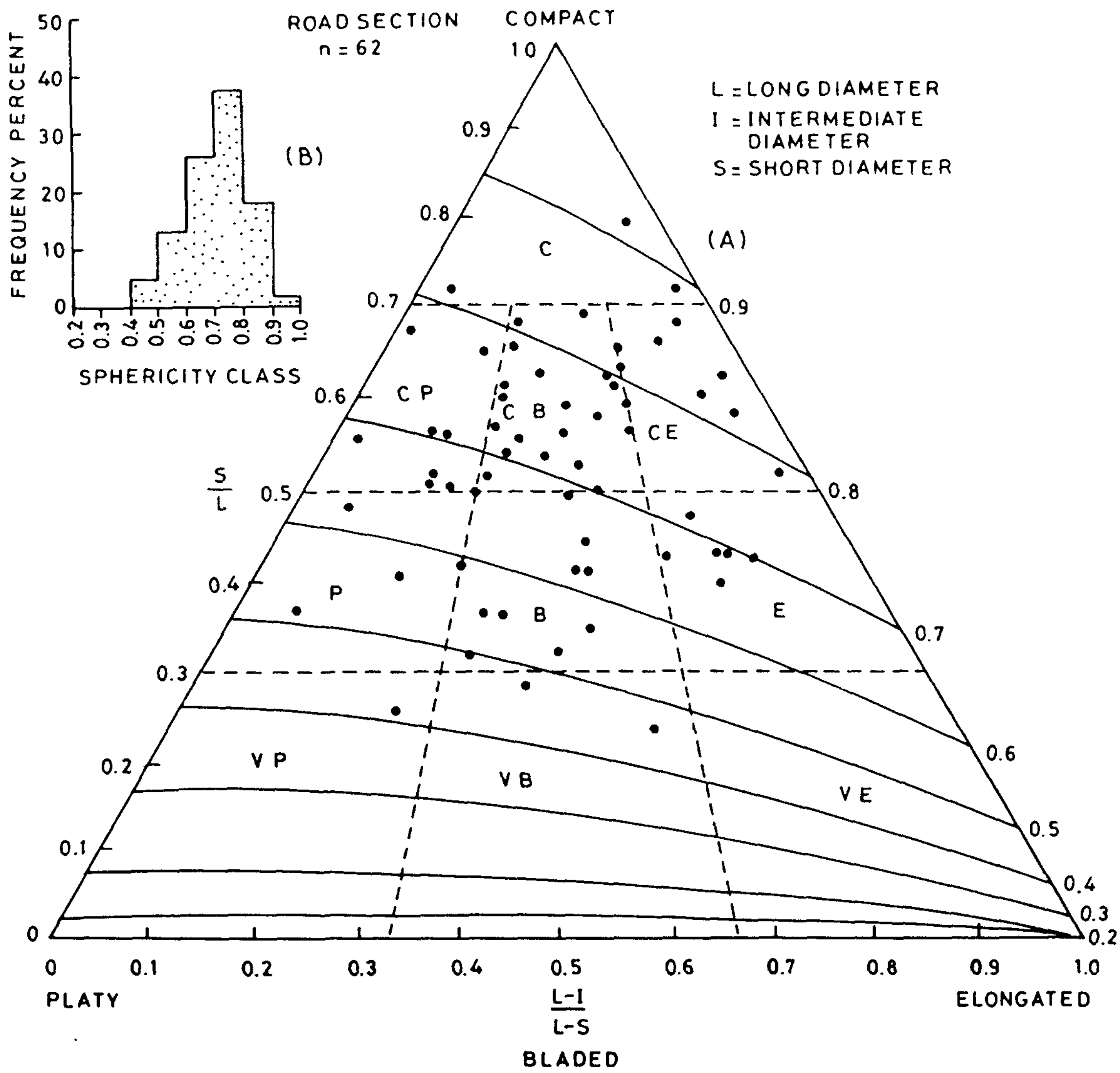

FIG. 8.(A) TRIANGULAR PLOT FOR SHAPE ANALYSIS OF CLASTS IN BASAL DIAMICTITE IN ROAD SECTION.
(B) HISTOGRAM SHOWING FREQUENCY DISTRIBUTION OF CLAST SPHERICITY FOR SAMPLE PLOTTED IN A.

followed closely by compact elongated (CE) shape (range 9.67 to 16.55, average 15.60). On an average these three shapes constitute asmuchas about 64% of the entire sample. The other shapes are compact platy (average 11.98%) and compact (average 10.45%).

Table 12 lists the sphericity statistics of clasts of basal diamictite obtained from data plotted on the triangular plots. The data are diagrammatically shown as histograms in Figures 6(B), 7(B) and 8(B). The frequency distribution of sphericity values in all localities is unimodal and significantly skewed towards lower sphericity values.

3.3.6. Clast Lithology and Granular Variation

A total of 1953 clasts (450 from Jhulna nala section, 603 from Tan Nadi and 540 from the Road section on the Ambikapur Road) from the basal diamictite were studied for their lithological composition. Table 13, sums up the results of clasts counts lithology-wise and size-wise at the above three localities.

The bar diagram in Figure 9 shows the percentages of various lithotypes embedded in the Basal diamictite in the Jhulna nala section. Granite and granite gneiss taken together and quartzites (smoky, pink and white) constitute the most abundant rock types, comprising 34% and 33% respectively by number of the whole sample. Clasts of red sandstone makeup

Table 12 : Sphericity statistics of clasts of Basal Diamictite.

Sphericity Class	Jhulna Nala (n = 79)			Tan Nadi (n = 151)			Road Section (n = 62)		
	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)
1.0-0.9	3.79			3.97			1.61		
0.9-0.8	17.72			22.51			17.74		
0.8-0.7	40.50			33.77			37.09		
0.7-0.6	26.58			25.16			25.80		
		0.723	0.108		0.723	0.113		0.704	0.111
0.6-0.5	8.86			12.58			12.90		
0.5-0.4	1.26			1.32			4.83		
0.4-0.3	1.26			0.66			-		

Table 13 : Result of clast counts lithology-wise and size-wise of Basal Diamictite (in per cent by number).

Size / Lithology	>256 mm	256-128 mm	128-64 mm	64-32 mm	32-16 mm	16-8 mm	8-4 mm	Total Per cent
Chuina Nala Section								
Granite and Gneiss	2.88	8.00	13.11	7.55	2.22	0.22	-	34.00
Quartzite	0.66	3.11	6.00	11.11	8.66	3.33	-	32.88
Sandstone	0.88	2.44	4.22	7.11	8.00	0.22	-	22.88
Greenstone and Basalt	-	0.44	1.77	3.11	1.33	-	-	6.66
Limestone and Chert	-	-	0.66	0.66	0.88	-	-	2.22
Phyllite/ Slate/ Schist	-	0.22	0.66	-	0.44	-	-	1.33
Tan Nadi Section								
Quartzite	0.16	1.16	2.15	8.62	12.93	8.62	3.81	37.47
Granite and Gneiss	-	1.16	4.47	8.45	8.12	5.63	1.32	29.18
Sandstone	-	-	0.99	2.65	4.97	5.47	2.81	16.91
Limestone and Chert	-	0.66	0.99	1.65	2.81	1.16	0.66	7.96
Phyllite/ Slate/ Schist	-	0.33	0.49	1.49	1.82	0.99	-	5.14
Greenstone/	-	-	0.16	0.99	0.99	0.99	0.16	3.31
Road Section								
Quartzite	-	0.55	1.48	12.40	17.40	9.44	4.81	46.11
Granite and Gneiss	-	0.18	1.85	7.96	7.59	6.85	2.96	27.40
Sandstone	-	-	0.55	5.37	5.55	3.70	1.66	16.85
Limestone	-	0.18	0.37	4.25	2.96	1.85	-	9.62

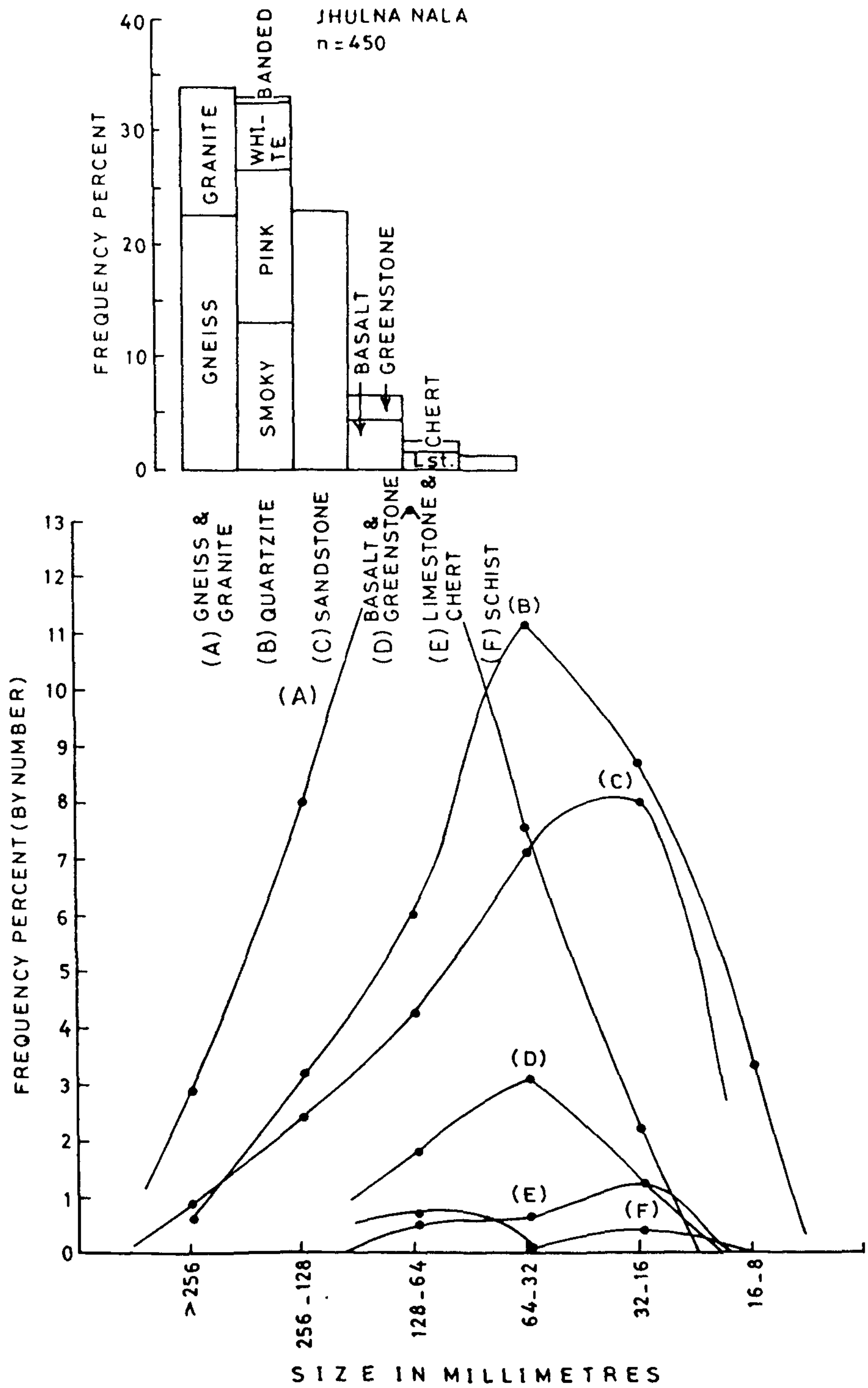

FIG. 9. PLOT SHOWING GRANULAR VARIATION IN CLASTS OF BASAL DIAMICTITE IN JHULNA NALA SECTION. INSET SHOWS GROSS COMPOSITION OF THE BASAL DIAMICTITE IN THE SAME SECTION.

about 23% by number of the sample studied. Thus the above named three lithologies makeup about 90% of the entire count. The remaining 10% comprise of the clasts of basalt and greenstone (6.66%), limestone and chert (2.22%) and schist/phyllite (1.33%).

Variation curves in Figure 9 show the relationship between clast composition and clast size in Jhulna nala area. Clasts of granite and gneiss are not only most abundant volumetrically but are also most numerous in sizes coarser than 64 mm meaning thereby that these two lithologies occur most commonly as cobbles and boulders. Their proportion steeply goes down in finer sizes. Their local derivation and coarse texture explains the nature of their granular variation. Clasts of quartzite most commonly occur as very coarse pebbles (32-64 mm) while red sandstone clasts are most numerous in the coarse pebble size (16-32 mm). The clasts of basalt and greenstone, though more susceptible to chemical and physical processes than quartzite, occur most commonly as very coarse pebbles, that is, in the same size class as the clasts of quartzites. This may suggest that clasts of this lithology have been derived from sources comparatively nearer as compared to from where quartzite clasts have been derived. Limestone and chert-clasts are more common in the coarse pebble grade (16-32 mm). The behaviour of schist/phyllite/slate clasts is rather different from the others inasmuch as their clasts, show abundance both in the cobble (64-128 mm) grade as well as in the coarse pebble grade (16-32 mm). This may suggest that clasts of these low to medium grade metamorphic rocks have been derived from two different sources.

In the Tan Nadi section a count of 603 clasts (Fig. 10) shows that quartzite (37%), granite and gneiss (29%), and red sandstone (17%) constitute the most important lithologies and together makeup about 83% by number of the whole count. Of the remaining lithologies present, limestone and chert constitute 7.96%, low grade metamorphics 5.14% and basalt and greenstone 3.31%.

The granular variation in clast composition is shown in Figure 10. The dominant lithologies in the cobble grade are granite, granite gneiss and quartzite. Since the diamictite exposed in this section is essentially a pebble diamictite the dominant lithology in this section is quartzite and not granite or granite gneiss because, for reasons discussed earlier, the clasts of latter composition tend to occur more commonly in the cobble grade. Lithologies occurring as coarse pebbles are quartzite, limestone and low grade metamorphics. Red sandstone clasts are more common in the 8-16 mm class (fine pebble) while clasts of greenstone and basalt are equally abundant in the 64-32, 32-16 and 16-8 mm classes.

540 clasts from the basal diamictite were studied for their composition and granular variation from the section exposed along the Ambikapur road (Fig. 11). Like the one

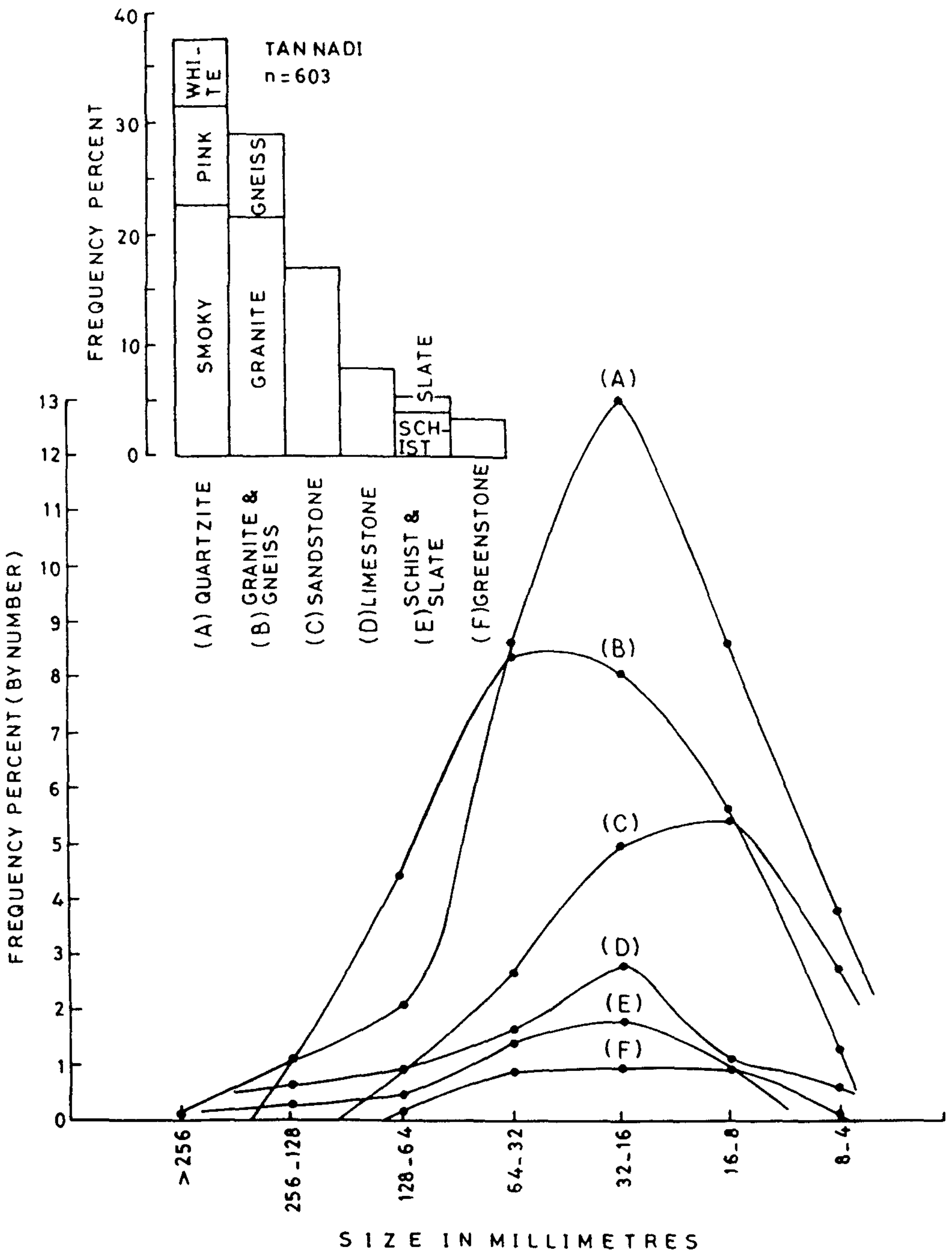

FIG.10. PLOT SHOWING GRANULAR VARIATION IN CLASTS OF BASAL DIAMICTITE IN TAN NADI SECTION. INSET SHOWS GROSS COMPOSITION OF THE BASAL DIAMICTITE IN THE SAME SECTION.

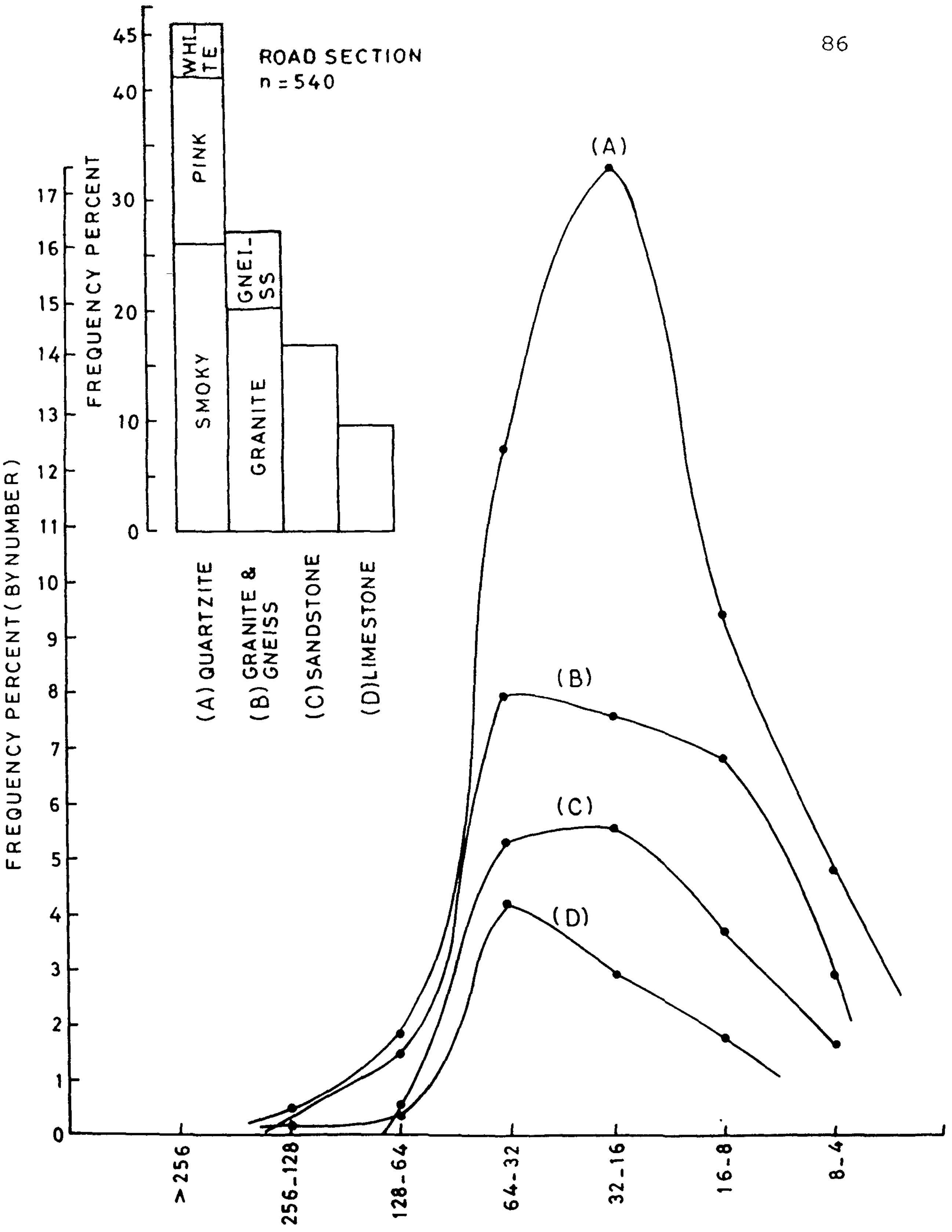

FIG.11 . PLOT SHOWING GRANULAR VARIATION IN CLASTS OF BASAL DIAMICTITE IN ROAD SECTION . INSET SHOWS GROSS COMPOSITION OF THE BASAL DIAMICTITE IN THE SAME SECTION .

exposed in Tan Nadi, this diamictite is also a 'pebble' diamictite and shows very close similarity to it. Clasts of quartzite are by far the most dominant lithology in these outcrops consisting about 46% by number followed by granite-granite gneiss (27%), red sandstone (17%) and limestone (about 10%).

Clasts of quartzites and sandstones occur most commonly in the coarse pebble grade (32-16 mm). Their percentage decreases rapidly in the coarser sizes and gradually in the finer sizes. In contrast, clasts of granite/gneiss and limestones are present in maximum numbers in the 64-32 mm size. Their frequency, like those of other lithologies, decreases rapidly in coarser sizes and gradually in finer grades.

3.3.7. Composition of Fine Fraction

The petrographic study of the fine fraction of the basal diamictite is based on the study of 12 representative thin sections from Jhulna nala, Tan Nadi and the Road Sections on the Ambikapur road. Most samples show very uniform characters but some contain abnormally high percentage of some constituents such as soft rock fragments and fragments of micritic limestone. Such samples are rare and do not represent the real character of the basal diamictite. Their nature and character have been discussed in the text but they have not been used for the purpose of modal analysis.

In thin sections an important and characteristic feature of the basal diamictite is its disrupted framework (Plate-10, Fig. 1). The framework constituents appear to float in a green coloured, almost opaque, paste like matrix. The question as to how far the framework is inherently disrupted and how far the disruption is secondary will be discussed alongwith the question of the origin of the matrix in a later part of this section.

The average modal composition of basal diamictite at the three localities where they are best exposed is given in Table 14. Each column represents the average of two thin section analyses.

Quartz : By far the most abundant among the grains of the framework is quartz, constituting between 66% to a little more than 84% of the rock by volume. A large number of grains of this mineral show strong to moderate wavy extinction suggesting, though not proving, their derivation from metamorphic source rocks. A relatively smaller percentage of the quartz grains, generally bigger in size than the ones described above, show sharp extinction and inclusions of tourmaline, zircon and rutile. It is possible that such grains of quartz may have been derived from the granitic source rocks.

The grains of quartz show wide range of roundness values - from angular to rounded (Plate-10, Fig. 1). However, the larger grains are slightly better rounded (arithmetic mean roundness

Table 14 : Modal Composition of Fine Fraction of Basal Diamictite
(Each column represents the average of two analyses).

omposition	Jhulna Nala 1		Jhulna Nala 2		Tan Nadi 1		Tan Nadi 2		Road Section 1		Road Section 2	
	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)
uartz	84.66	0.373	81.00	0.352	72.33	0.315	66.00	0.325	84.66	0.362	80.00	0.340
eldspar	3.66	0.520	5.33	0.400	4.33	0.355	6.33	0.372	5.66	0.139	8.00	0.340
ock Fragments												
uartzite/ uartz Schist	3.66	0.424	2.00	0.312	4.00	0.355	3.00	0.283	2.66	0.175	3.00	0.341
hyllite/ late	4.00	0.430	3.00	0.283	7.00	0.297	3.66	0.352	0.66	0.237	2.00	0.312
ranite/ ranitic Gneiss	-	-	-	-	-	-	2.33	0.275	0.33	0.400	0.66	0.400
icritic imestone	-	-	2.00	0.500	-	-	5.66	0.438	0.56	0.390	0.66	0.400
hert	1.0	0.600	2.00	0.400	-	-	2.33	0.275	1.66	0.235	0.66	0.400
ccessories	2.99	0.360	4.66	0.340	12.33	0.530	10.65	0.320	4.00	0.270	4.99	0.350

EXPLANATION OF PLATE X

Figure 1 Photomicrograph of matrix of basal diamictite showing moderate sorting and disrupted framework. Grains of feldspar are sub-rounded and slightly altered. Quartz grains are mostly sub-angular.

Ordinary light x 10

Figure 2 Photomicrograph of matrix of basal diamictite showing large sub-rounded grain of microcline.

Cross-nicol x 30

Figure 3 Photomicrograph of matrix of basal diamictite showing normal framework. Plagioclase grains are sub-angular to sub-rounded.

Cross-nicol x 75

PLATE X

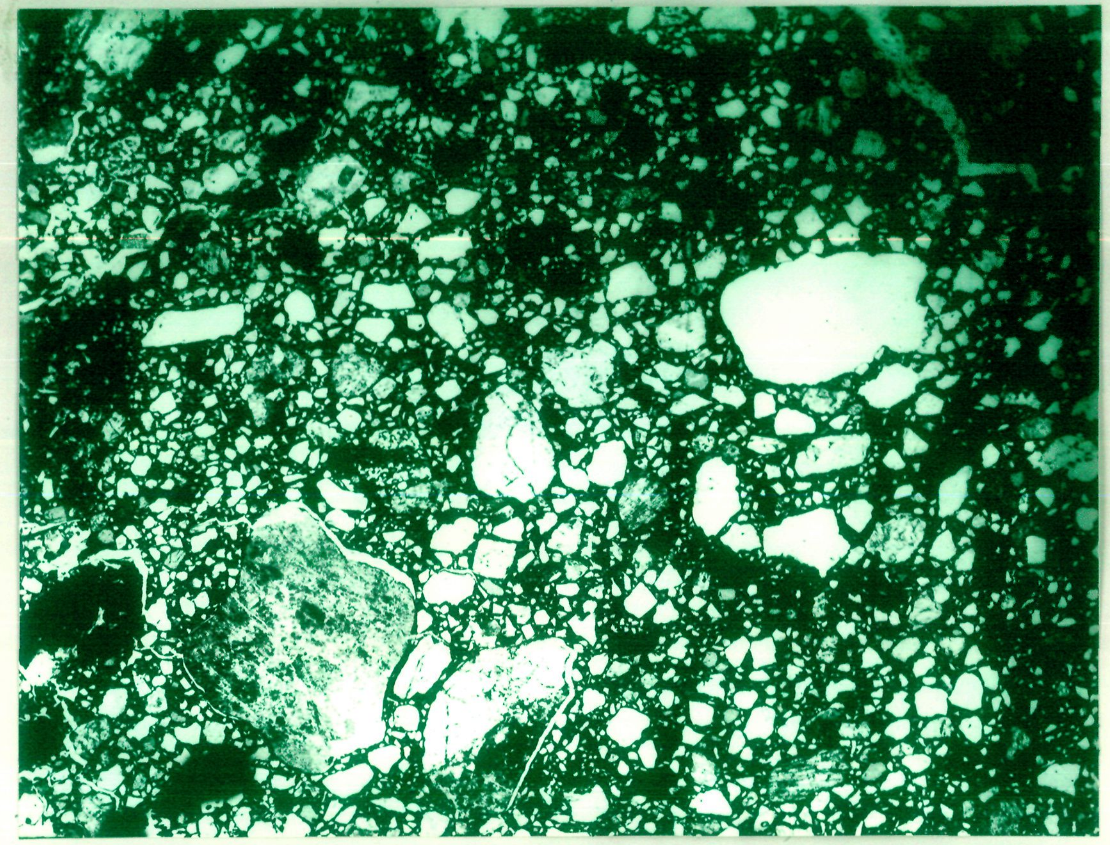

Fig. (x 10)

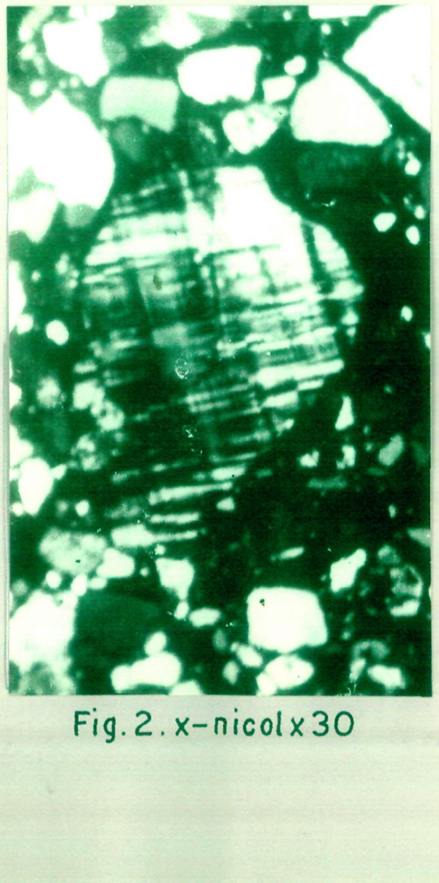

Fig. 2. x-nicol x 30

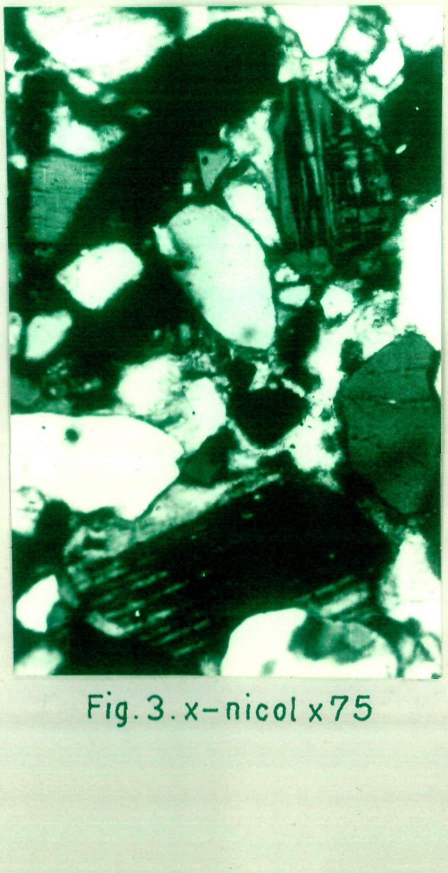

Fig. 3. x-nicol x 75

0.396) than the smaller grains (arithmetic mean roundness 0.291). Taken as a whole the grains of quartz are sub-rounded (arithmetic mean roundness 0.344).

Feldspars : Feldspars form a relatively small proportion of the rock by volume varying in amount from about 4% in some specimen up to 8% in others. Both potash and soda varieties are present. Grains of microcline and perthite are generally bigger in size and generally rounded to sub-rounded (Plate-10, Figs. 1 & 2). However, plagioclase grains occur generally in smaller size and show angular to sub-angular outline (Plate-10, Fig. 3).

Potash feldspars show all stages of alteration from absolutely fresh grains showing perfect cleavage and twinning (Plate-10, Figs. 2 & 3), to considerably altered grains (Plate-10, Fig. 1). The highly altered grains when crushed between the more resistant grains of quartz, are often indistinguishable from the fine, paste like matrix.

Rock Fragments : Rock fragments are present in the fine fraction of the basal diamictite ranging from 7% to 17% by volume and exhibits a very wide range of composition.

Soft rock fragments such as chlorite-phyllite, chlorite-schist, sericite-phyllite, calcareous phyllite and slate, constitute the most abundant type. Such rock fragments occur both as distinct grains (Plate-11, Fig. 1) and also in crushed condition between harder grains (Plate-11, Fig. 2). All stages of crushing can be seen in such fragments so much so that they become indistinguishable from the matrix.

Fragments of metamorphic quartzite are generally angular to sub-angular and occur in much bigger size (Plate-11, Fig. 3). The constituent grains of quartz show wavy extinction and sutured contacts and are comparable in their size and characters to the quartz grains of the same size occurring in the matrix as separate grains. It is very likely that a part of the quartz grains occurring as separate entities in the matrix may have been derived from the break up of the larger quartzite fragments.

Fragments of granite and granite-gneiss are also present in most specimens studied. Such composite fragments are very angular and contain grains of quartz, feldspars and often mica comparable in size to the medium sized quartz and feldspar grains occurring as individual grains in the matrix. This feature suggests that quartz and feldspars may have been contributed to the fine fraction of the diamictite by the crushing of granite fragments.

Fragments of sedimentary rocks are represented by quartz-arenite, chert and microcrystalline limestone. Grains of quartz-arenite are angular to sub-angular and the constituent well rounded quartz grains show authigenic overgrowth around them (Plate-11, Fig. 4). Chert grains are of smaller size and show rounded to well-rounded outlines (Plate-11, Fig. 5). Fragments

EXPLANATION OF PLATE XI

Photomicrograph of Matrix of Basal Diamictite

Figure 1 Showing poor sorting of the matrix. The large grain in the centre of the photograph is that of shale.. The margin of this grain serrated due to marginal crushing.

Cross-nicol x 30

Figure 2 Dark grains of soft rock fragments are partially squeezed between harder grains.

Note moderate sorting of the matrix and sub-angular nature of quartz grains.

Ordinary light x 30

Figure 3 A large sub-angular grain of quartzite seen in the central part of the photograph. Quartz grains are angular to sub-angular but smaller than the grain of quartzite.

Ordinary light x 30

Figure 4 A large grain of quartz arenite. Individual grains show sub-rounded outlines and are coated with a thin film of iron oxide.

Ordinary light x 30

Figure 5 A well rounded grain of chert in the lower right hand corner of the photographs. Quartz grains are sub-angular to sub-rounded.

Ordinary light x 30

Figure 6 Large scale corrosion of quartz grain by sparry calcite cement.

Note that the vestiges of quartz grains are sharply angular.

Ordinary light x 75

PLATE XI

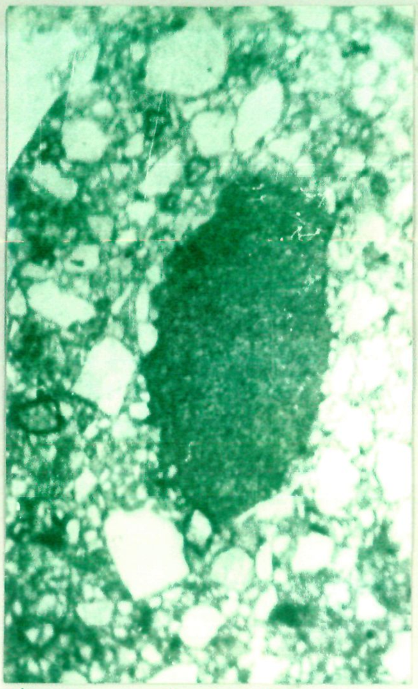

Fig. 1. x-nicol x 30

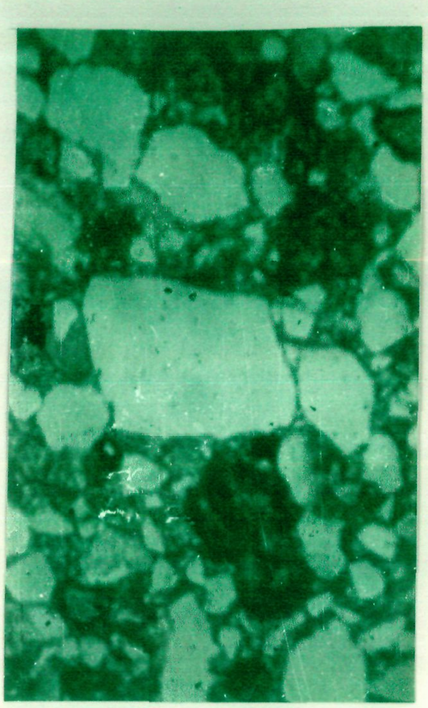

Fig. 2. Ordinary light x 30

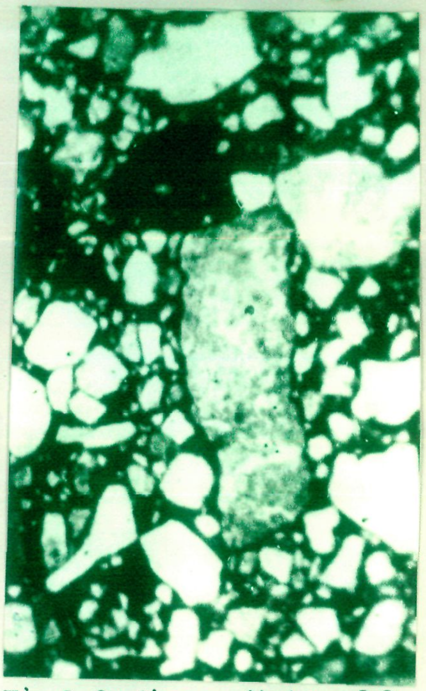

Fig. 3. Ordinary light x 30

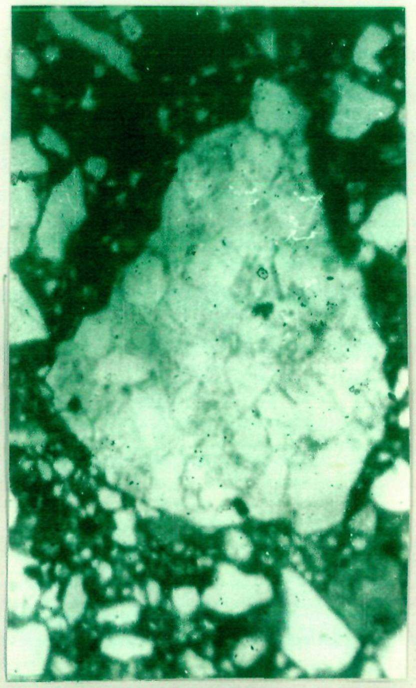

Fig. 4. Ordinary light x 30

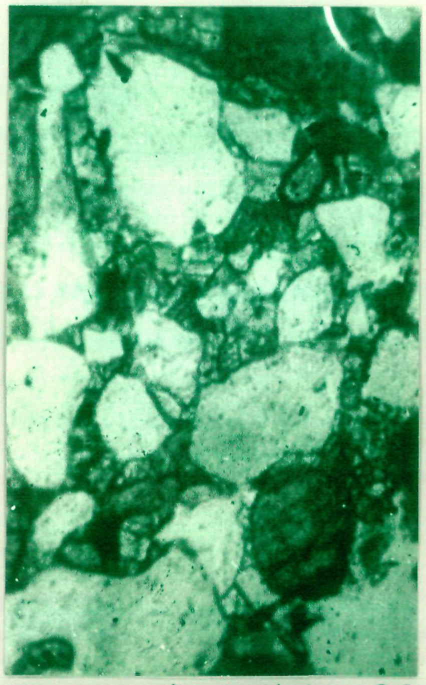

Fig. 5. Ordinary light x 30

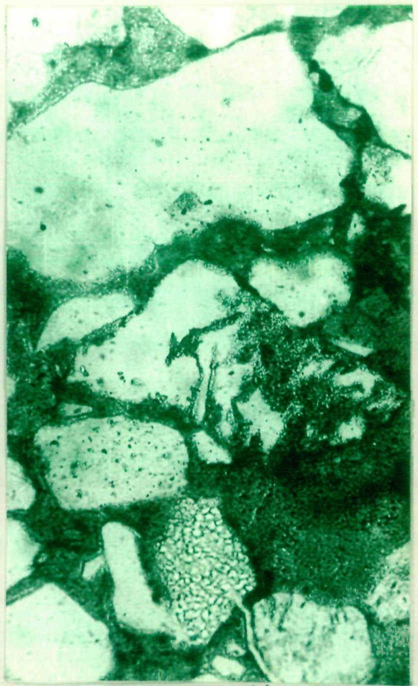

Fig. 6. Ordinary light x 75

of microcrystalline carbonate rocks are rounded to sub-rounded.

As mentioned earlier, the framework of the fine fraction of the basal diamictite is disrupted and the framework constituents float in a very fine grained, paste like, green coloured matrix constituting 20%to 30% of the rock by volume.

Evidence has been cited in the foregoing pages that at least a part of the matrix is of secondary origin having being generated as a result of crushing of altered feldspar grains and clasts of granite, low grade metamorphic rocks such as chlorite-schist and greenstones. This has resulted in accentuating the disruption of the framework of the rock. In some samples from Muria nala, sparry calcite cement occurs in patches, and there is large scale corrosion of quartz grains somuch so that at places disrupted framework appears as a result of replacement by calcite cement (Plate-11, Fig. 6).

It appears that even after making allowance for secondary matrix, the initial amount of matrix in the fine fraction of the basal diamictite was more than 15% and thus can be classified as 'wacke' rather than 'arenite' (Casshyap, 1967, 1969). Figure 12 shows the position of samples of fine fraction in the classificatory scheme proposed by Casshyap (1967, 1969). It is observed that 5 samples can be classified as sublithwacke while only one as subarkosic wacke.

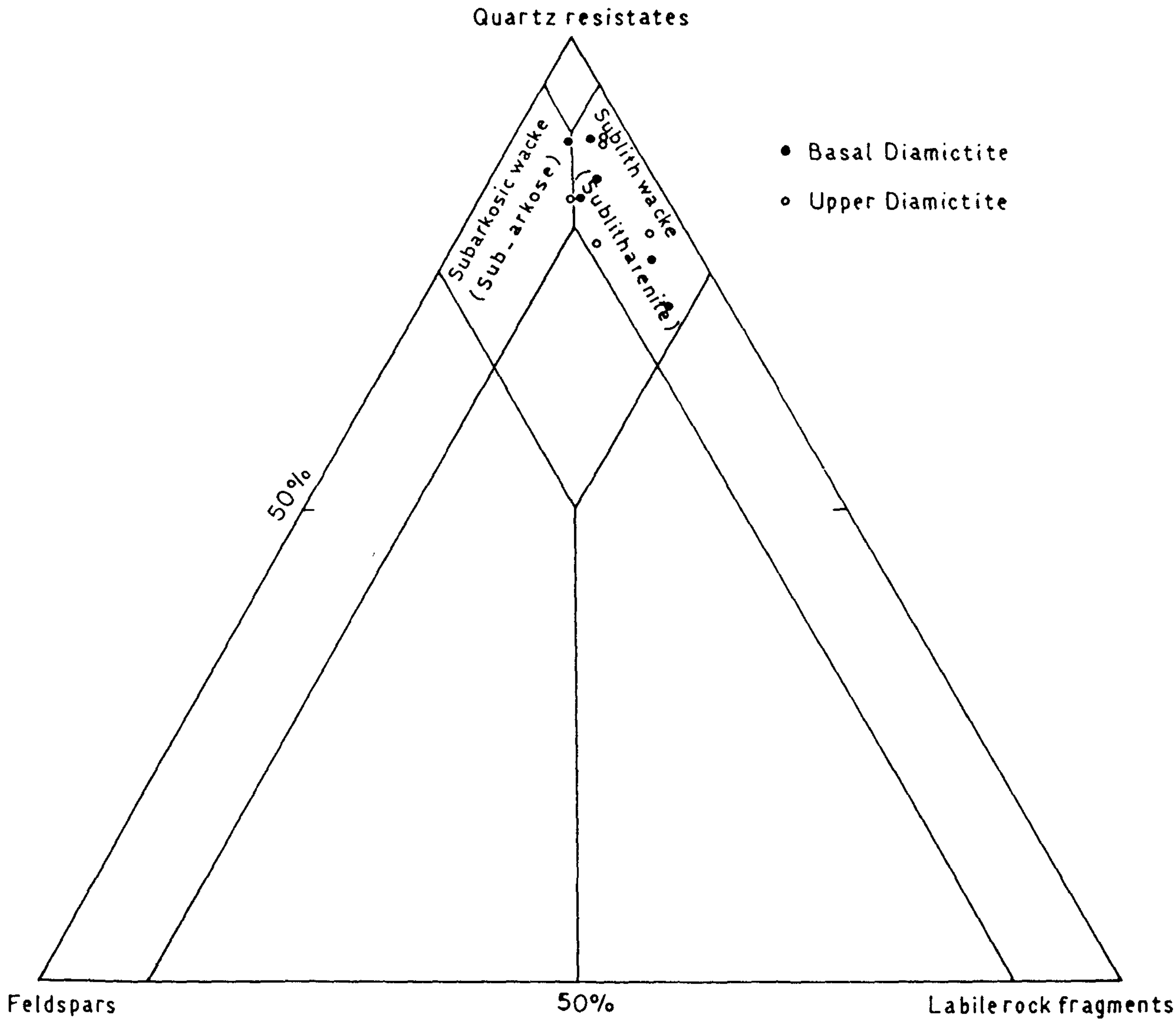

FIG. 12. CLASSIFICATION OF FINE FRACTIONS OF TALCHIR DIAMICTITES. THE MATRIX OF BASAL DIAMICTITE UNITS ARE CLASSIFIED AS 'WACKES' AND THAT OF UPPER AS 'ARENITES'.

3.3.8. Heavy Minerals

As mentioned earlier, an examination of the heavy mineral crops obtained from the fine fractions of the two diamictite units and the various lithofacies of the sandstones show remarkable similarity in quality and quantity. To avoid repetition, the description of the heavy mineral species have been given only at one place. The photographs of the heavy minerals from all lithounits are given in Plate-12.

Altogether 9 samples of the matrix of the basal diamictite, three each from Jhulna *nala*, Tan *Nadi* and road sections were selected for heavy mineral studies. A total of 4355 heavy mineral grains were counted in nine samples care,being taken not to count less than 400 grains in each sample. The percentage by number of each heavy mineral species is given in Table 15.

Garnet : Garnet is the most abundant mineral of the heavy mineral assemblage constituting 84.91% in Jhulna *nala*, 89.75% in Tan *Nadi* and 86.55% in the road section (Average 87.06). Two varieties of garnet, colourless (77.45%) and pink (8.86%), are distinguished. The grains generally are sub-angular to sub-rounded and often show pitted or etched surface. Inclusions of zircon and tourmaline are not uncommon in the two varieties.

PLATE XII

Plate showing the different characters of heavy minerals of the diamictite units and sandstones in the study area.

Note : The description of characters of heavy minerals is given elsewhere in the text.

PLATE XII

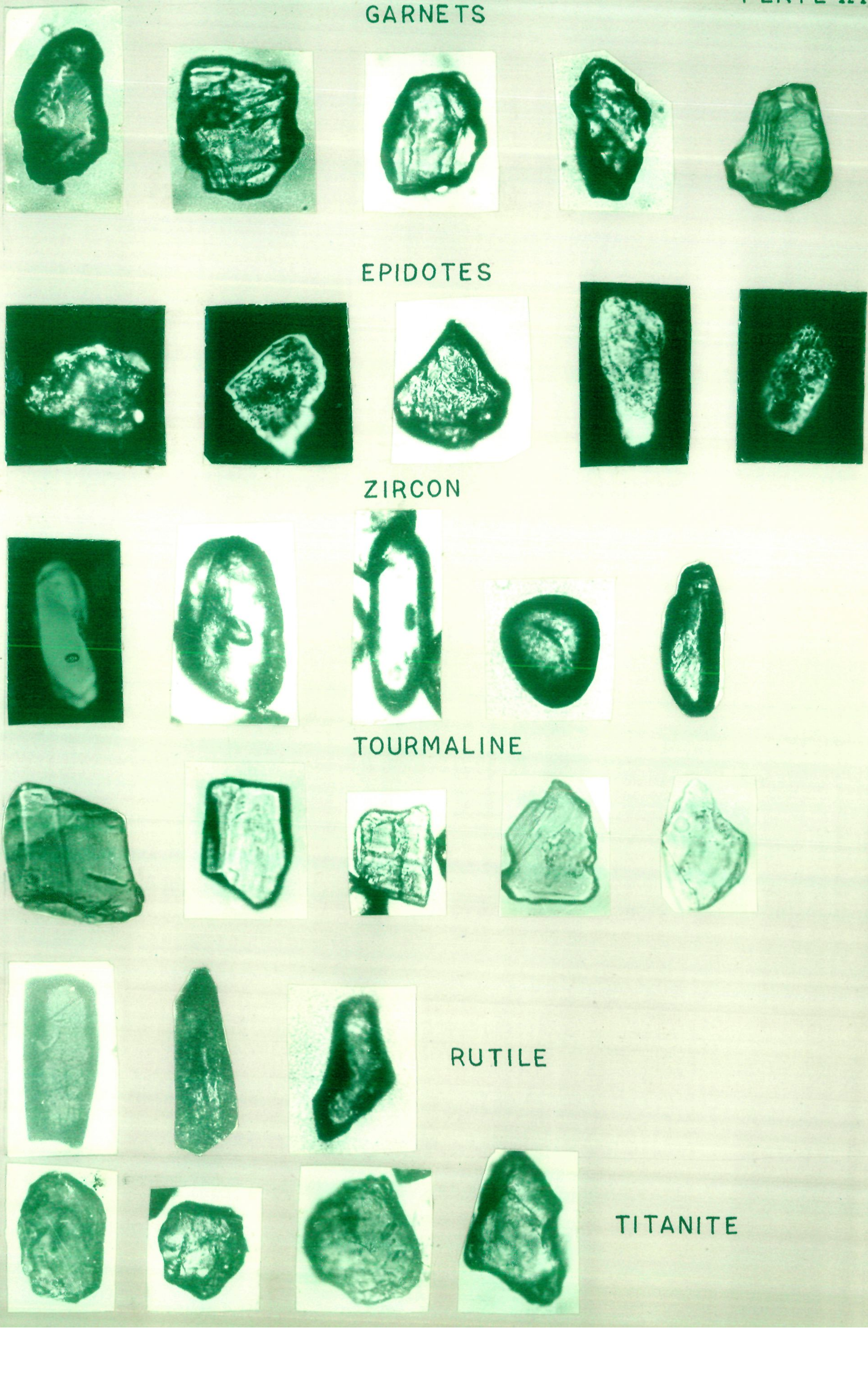

Table 15 : Average Heavy Mineral Composition of Fine Fraction of Basal Diamictite (Per cent by number)

White Garnet	Pink Garnet	Epidote	Zircon	Tourm-aline	Muscovite	Rutile	Titanite	Biotite	Apatite	Opaque
Jhulna Nala (Average of 3 samples)										
77.71	7.20	3.93	1.05	0.30	0.41	0.48	0.56	-	0.03	8.85
Tan Nadi (Average of 3 samples)										
78.84	10.91	3.65	0.66	0.53	0.46	0.33	0.53	0.13	-	3.99
Road Section (Average of 3 samples)										
73.65	12.90	2.68	0.53	0.53	1.07	-	-	0.53	-	8.06
Average										
76.73	10.33	3.42	0.74	0.45	0.64	0.27	0.36	0.22	0.01	6.96

Opaques : Opaques are the next in abundance to garnet constituting 3.99% to 8.85% (average 6.96%) of the entire heavy mineral count. Among the opaques, magnetite and ilmenite have been identified but no attempt has been made to count them separately. The grains are irregular, black and opaques and are common to fairly abundant in all the sections of the basal diamictite.

Epidote (Pistacite) : The amount of epidote in different samples varies from 2.68% to 3.93% (average 3.42%). It shows its characteristic greenish yellow colour and week but distinctive pleochroism and high birefringence. The grains are generally sub-rounded and the majority of the grains show 'compass needle' interference figure.

Zircon : This mineral is common in all the three sections of the basal diamictite. The grains show a great variation in their outlines from well formed euhedral crystals to well-worn grains. More commonly the zircons are rounded to well-rounded. Inclusions of rutile are also present in certain grains.

Micas : Among the micas muscovite is predominant and shows its usual characters and constitutes 0.34% to 0.46% (average 0.45%) of the heavy mineral crop. Biotite (0.13%to 0.53%, average

0.04%) occurs in deep brown colour blotchy irregular cleavage flakes.

Tourmaline : Tourmaline occurs in two varieties, namely, brown and yellow and its amount varies from 0.30%to 0.53% (average 0.45%). It is strongly pleochroic and is sub-rounded to rounded. In some grains authegenic growths are observed.

Rutile : Rutile is blood red to orange red in colour with irregular to sub-rounded boundaries and constitutes 0.33%to 0.48% (average 0.27%) of the total heavy mineral assemblage.

Titanite : Titanite, usually of colourless variety, occurs as sub-angular to sub-rounded grains and occurs to the extent of 0.53% to 0.56% (average 0.36%) of the total heavy mineral crop. It shows same colours under crossed-nicols as in ordinary light due to very high birefringence. The grains become light blue as the extinction position is reached.

Apatite : Apatite is present only in the Jhulna nala section in very small amount (0.03%). It is colourless with sub-rounded to rounded outlines. Few grains show cross fractures. It gives first order grey interference colour, and in crossed nicols it becomes nearly dark due to very low birefringence.

3.4. UPPER DIAMICTITE

3.4.1. Mechanical Composition of Coarse Fraction

The upper diamictite is best exposed at three localities in the study area, namely, at and around the P.W.D., Rest House at Marhai, near the bridge on the Hasdo river on the road going to Ambikapur and in the Kharpari nala - Korbi section. A total of 1378 clasts were studied for their size frequency distribution at 10 outcrops in the three localities mentioned above. The break up of the number of measurements made at each outcrop is given below.

	PWD Rest House Marhai	Hasdo River bridge on Ambikapur Road				Kharpari nala - Korbi Section					Total
Outcrop No.	1	1	2	3	4	1	2	3	4	5	10
Number of clasts measured	102	176	133	146	105	160	97	148	109	202	1378

Table 16 presents the results of size analysis of the coarse fraction at various outcrops. Figure 13 presents the same data as histograms. Of the 10 samples analysed only one sample

Table 16 : Mechanical Composition of Coarse Fraction of the Upper Diamictite (Percentage by number)

Class(mm)	PWD Rest House	Road Bridge				Kharpari Nala - Korbi				
	1	1	2	3	4	1	2	3	4	5
>256	-	-	-	-	-	-	-	-	-	-
256-128	0.98	-	-	-	2.85	-	-	-	-	-
128-64	4.90	14.20	6.76	3.42	11.42	0.62	2.06	3.37	4.58	14.85
64-32	22.54	35.52	23.30	28.08	33.28	20.62	16.49	19.59	25.68	38.61
32-16	26.47	23.29	26.31	39.04	35.28	33.75	25.77	33.78	34.86	29.20
16-8	27.45	18.75	19.54	16.43	15.23	23.12	28.86	30.40	18.34	12.87
8-4	17.64	10.22	24.06	13.01	1.90	21.87	26.80	12.83	16.51	4.45

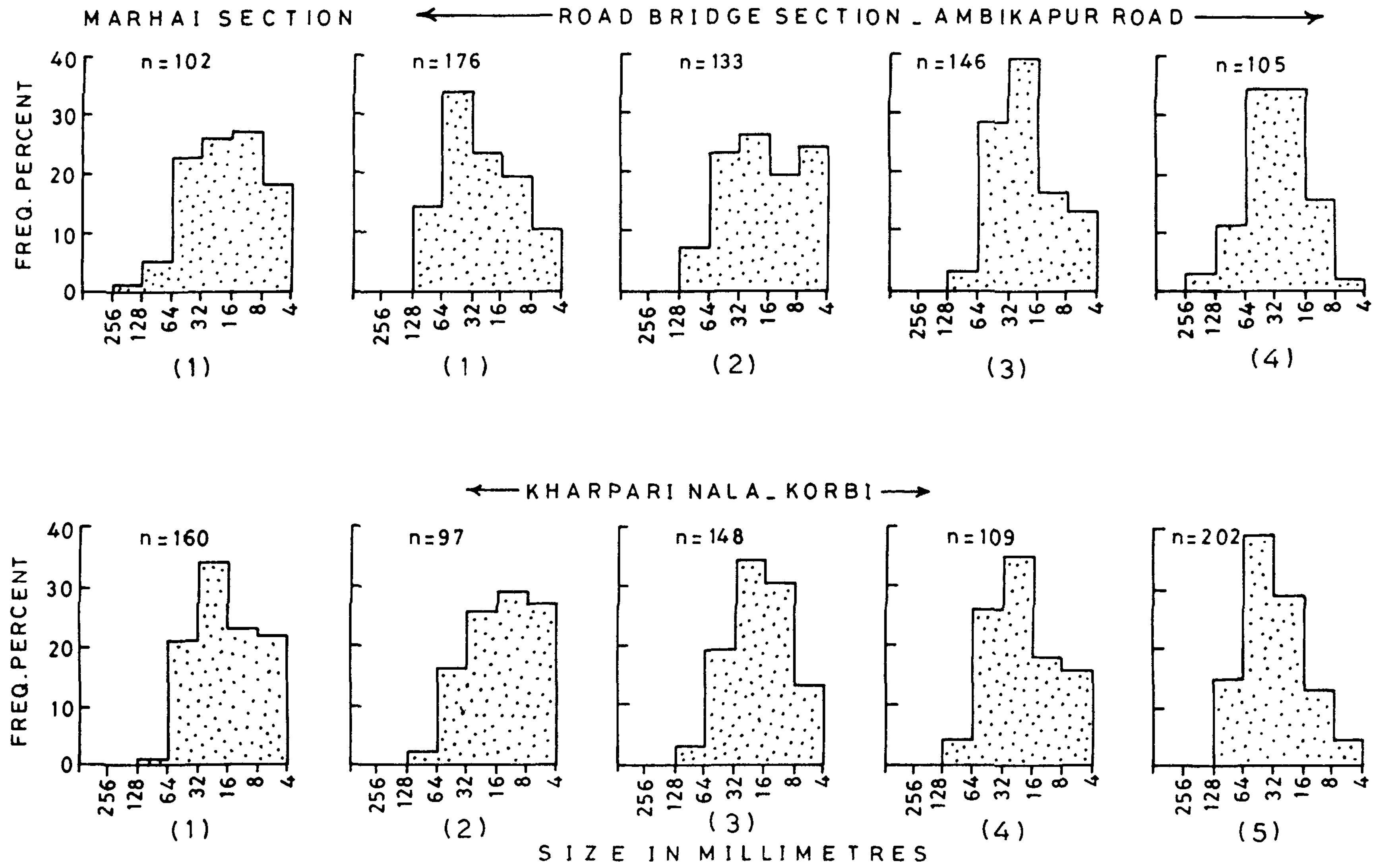

FIG.13. HISTOGRAMS SHOWING THE SIZE FREQUENCY DISTRIBUTION OF COARSE FRACTION OF UPPER DIAMICTITE.

(outcrop No. 2 in the road bridge section) is bimodal, the remaining 9 show unimodal size frequency distribution. The modal class in the sample from Marhai and from sample 2 from Kharpari nala lies in the 16-8 mm class while in 6 samples it lies in the 32-16 mm class. Only in two samples does it lie in the 64-32 mm class. The number of classes containing more than 5% of the material is 4 to 5 in the various samples indicating that the size frequency distribution is moderately sorted. In 7 out of 10 samples studied the size frequency distribution is fine skewed, in two samples it is coarse skewed while in one it is near symmetrical. The amount of material in the modal class in the various samples varies from 26% to 39% and, therefore, the peakedness of the distribution is moderate.

When the data on mechanical composition of the coarse fractions of basal and upper diamictites are compared it is found that there is not much difference between the two in respect of their size characteristics except that the upper diamictite is on an average a little finer grained and more fine skewed.

3.4.2. Mechanical Composition of Fine Fraction

Table 17 presents the results of five thin section size analysis of the fine fraction of upper diamictite from the three localities where best outcrops of the upper

Table 17 : Mechanical Composition of fine fraction of Upper Diamictite.

Size Class		Marhai				Road Bridge		Kharpari Nala - Korbi			
mm scale	Ø scale	Frequency Per cent	Cumulative Per cent	Frequency Per cent	Cumulative Per cent	Frequency Per cent	Cumulative Per cent	Frequency Per cent	Cumulative Per cent	Frequency Per cent	Cumulative Per cent
1.41-1.00	0.0	-	-	0.33	0.33	-	-	0.33	0.33	-	-
1.00-0.71	0.5	-	-	0.33	0.66	-	-	0.66	0.99	0.33	0.33
0.71-0.50	1.0	0.66	0.66	0.66	1.33	0.66	0.66	1.00	1.99	0.33	0.66
0.50-0.35	1.5	1.33	1.99	2.00	3.33	2.00	2.66	1.66	3.99	0.66	1.33
0.35-0.25	2.0	4.33	6.33	4.00	7.33	5.66	8.33	2.00	5.66	1.66	2.99
0.25-0.177	2.5	11.33	17.65	9.00	16.33	9.33	17.66	9.66	15.33	4.66	7.66
0.177-0.125	3.0	17.33	34.99	19.00	35.33	21.00	38.66	12.33	27.66	6.00	13.66
0.125-0.088	3.5	28.33	63.33	20.33	55.66	30.00	68.66	13.00	40.66	13.00	26.99
0.088-0.062	4.0	15.33	77.33	19.33	74.99	11.00	78.99	16.00	56.66	13.33	39.99
0.062-0.044	4.5	14.33	92.66	13.33	88.33	10.33	89.99	24.66	81.33	28.66	68.66
0.044-0.031	5.0	6.66	99.33	10.00	98.33	7.00	96.99	17.00	98.33	21.33	89.99
0.031-0.015	5.5	0.66	99.99	1.66	99.99	3.00	99.99	1.66	99.99	10.00	99.99

diamictite occur. Figure 14 shows the average size frequency distribution represented as histograms and cumulative curves for each area. It is noteworthy that the size frequency distribution of the fine fraction of the upper diamictite is unimodal in all samples studied in contrast to the bimodal character of the same fraction of the basal diamictite. In the Marhai and Road Bridge sections the modal class lies in the 3.0 - 3.5 ∅ (very fine sand) class while in the Kharpari nala-Korbi section it lies in the 4.0 - 4.5 ∅ (coarse silt) class. The spread of the data as shown by the number of half-phi classes containing more than 5% of material, is 6 to 7 in the various sections studied.

Table 18 gives the statistical parameters of the size frequency distribution of the fine fraction of the upper diamictite. In all samples the value of Mz lies in the very fine sand class. All samples are moderately sorted and whereas 3 samples are coarse skewed, only 2 are fine skewed. Further 3 samples are meso-kurtic while 2 are lepto-kurtic.

3.4.3. Roundness Characteristics of Coarse Fraction

372 clasts from various outcrops of the upper diamictite were studied for their roundness characteristics (Table 19). The same data are shown in Figure 15(A) as histograms. At all localities studied the chief ingredient lies in the sub-rounded

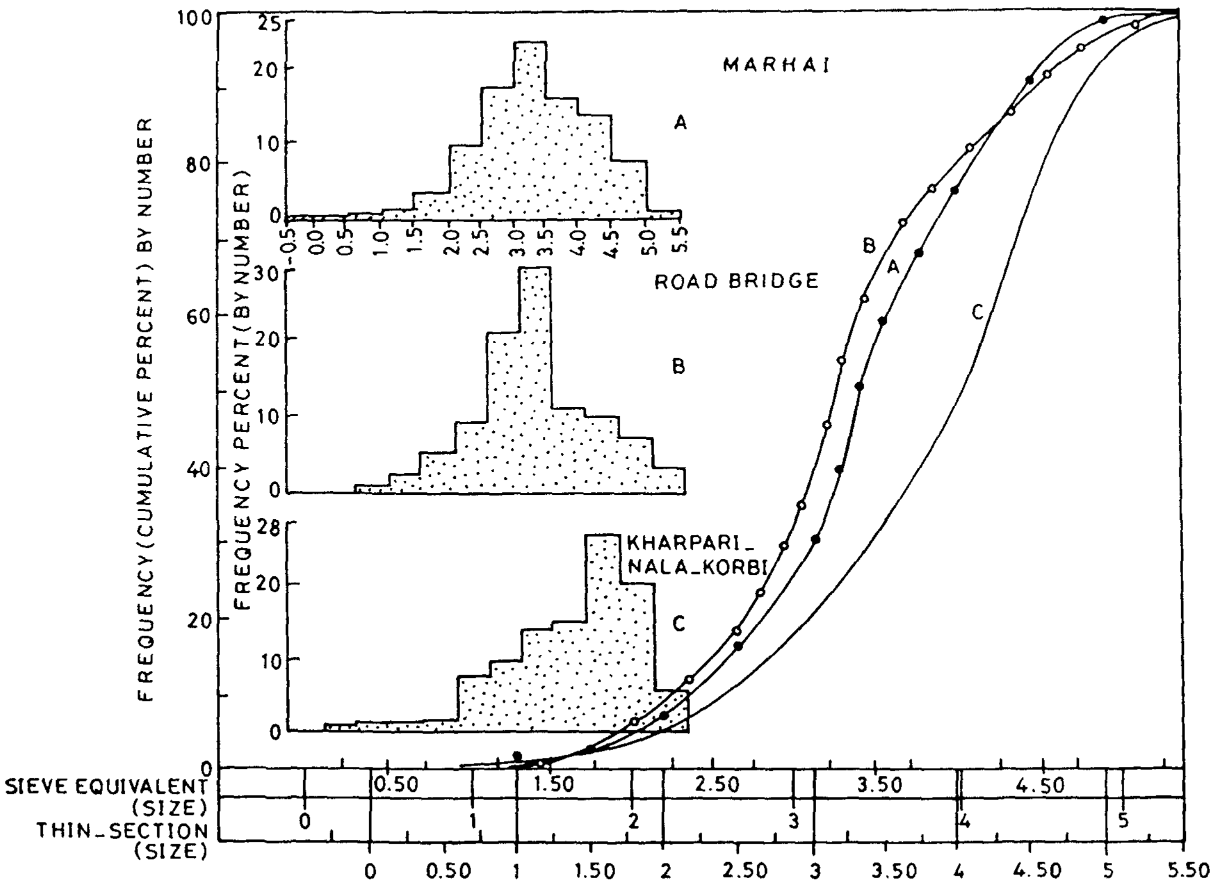

FIG.14. HISTOGRAMS AND CUMULATIVE CURVES SHOWING SIZE FREQUENCY DISTRIBUTION OF FINE FRACTION OF UPPER DIAMICTITE .

Table 18 : Statistical Characteristics of size frequency distribution of fine fraction of Upper Diamictite.

Locality	Graphic Mean (Mz)	Inclusive Graphic Standard Deviation (σ_1)	Inclusive Graphic Skewness (SKI)	Graphic Kurtosis (KG)	Uni/Poly modal
Marhai	3.35	0.793 (Moderately sorted)	0.131 (Fine skewed)	0.968 (Meso-kurtic)	Unimodal
	3.46	0.849 (Moderately sorted)	-0.021 (Coarse skewed)	1.107 (Meso-kurtic)	Unimodal
Road Bridge	3.35	0.846 (Moderately sorted)	0.118 (Fine skewed)	1.25 (Lepto-kurtic)	Unimodal
Kharpari Nala	3.68	0.865 (Moderately sorted)	-0.274 (Coarse skewed)	1.381 (Lepto-kurtic)	Unimodal
Hasdo River -Korbi	4.00	0.809 (Moderately sorted)	-0.236 (Coarse skewed)	1.018 (Meso-kurtic)	Unimodal

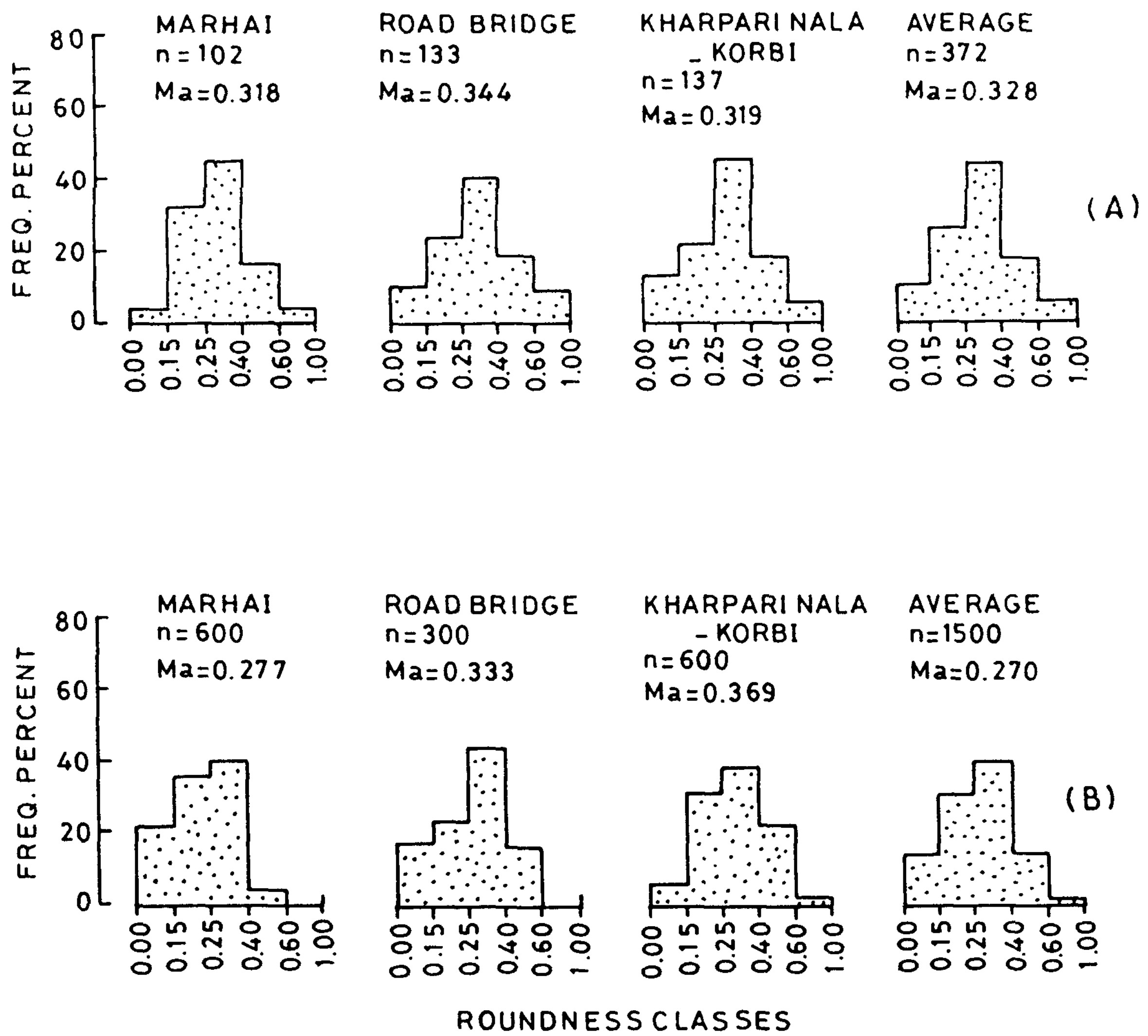

FIG.15. HISTOGRAMS SHOWING THE DISTRIBUTION OF ROUNDNESS VALUES OF
(A) CLASTS EMBEDDED IN UPPER DIAMICTITE
(B). GRAINS COMPRISING FINE FRACTION OF UPPER DIAMICTITE .

Table 19 : Roundness Statistics of Clasts in Upper Diamictite.

Roundness Class	Marhai (n = 102)			Road Bridge (n = 133)			Kharpari Nala-Korbi(n = 137)			Average (n = 372)		
	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)
Angular 0.00–0.15	3.92			9.77			12.40			9.13		
Sub-angular 0.15–0.25	32.35			23.30			21.16			25.00		
		0.318	0.105		0.344	0.177		0.319	0.152		0.328	0.159
Sub-rounded 0.25–0.40	44.11			39.84			45.25			43.01		
Rounded 0.40–0.60	15.68			18.79			16.78			17.20		
Well-rounded 0.60–1.00	3.92			8.27			4.37			5.64		

class and the arithmetic mean roundness values range from 0.318 to 0.344. The data are spread in all the five roundness classes in all samples and the peakedness of the modal class is moderate to low.

A comparison of the roundness characteristics of clasts in the basal and upper diamictite shows that the latter differs from the former in the following aspects.

Roundness Characteristics	Basal Diamictite (Average)	Upper Diamictite (Average)
1. Percentage material in modal class	55.55	43.00
2. Percentage of clasts in 'rounded' class	10.72	17.20
3. Percentage of clasts in 'well-rounded' class	3.06	5.64
4. Mean roundness	0.306	0.328

3.4.4. Roundness Characteristics of Fine Fraction

Table 20 shows the results of roundness studies of grains constituting the fine fraction of upper diamictite studied in thin sections. Same data are shown as histograms in Figure 15(B). The data show that in all localities the

Table 20 : Roundness statistics of fine fraction of Upper Diamictite.

Roundness Class	Marhai (n = 600)			Road Bridge (n = 300)			Kharpari Nala-Korbi (n = 600)			Average (n = 1500)		
	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)	Frequency Per cent	Arithmetic Mean (Ma)	Standard Deviation (σ a)
Angular 0.00-0.15	21.33			17.66			6.166			14.53		
Sub-angular 0.15-0.25	35.16			23.33			32.83			31.86		
		0.277	0.140		0.333	0.166		0.369	0.159		0.325	0.159
Sub-rounded 0.25-0.40	39.50			43.00			37.83			39.53		
Rounded 0.40-0.60	4.00			16.00			23.00			14.00		
Well-rounded 0.60-1.00	-			-			0.166			0.066		

roundness modal class lies in the 0.25 to 0.40 (sub-rounded) class. However, all distributions are skewed towards the angular grades and the peakedness of the frequency distribution is moderate. A comparison with the same data from the basal diamictite show that on an average the roundness of grains of the fine fraction of the upper diamictite are slightly more rounded than those of the basal diamictite.

3.4.5. Shape and Sphericity of Clasts

247 clasts from the upper diamictite were subjected to an analysis of their shape and sphericity. Following the method of Sneed and Folk (1958) the data have been plotted in triangular diagrams as Figures 16(A), 17(A) and 18(A). Table 21 summarises the shape characteristics of clasts from Marhai, Road Bridge section on the Hasdo River and the Kharpari nala-Korbi sections. The most common shape of clasts in the Marhai section is compact elongated (30.61%). Other important shapes acquired by the clasts in this section are compact bladed (16.32%), compact (14.28%), bladed (14.28%) and platy (12.24%). In the Road Bridge and Kharpari nala-Korbi sections, the compact-bladed clasts are most abundant constituting 31.18% and 20.95% respectively. Other important shapes in these two localities in order of abundance are compact-elongated compact-platy, bladed and compact. It is seen that there is a greater diversification

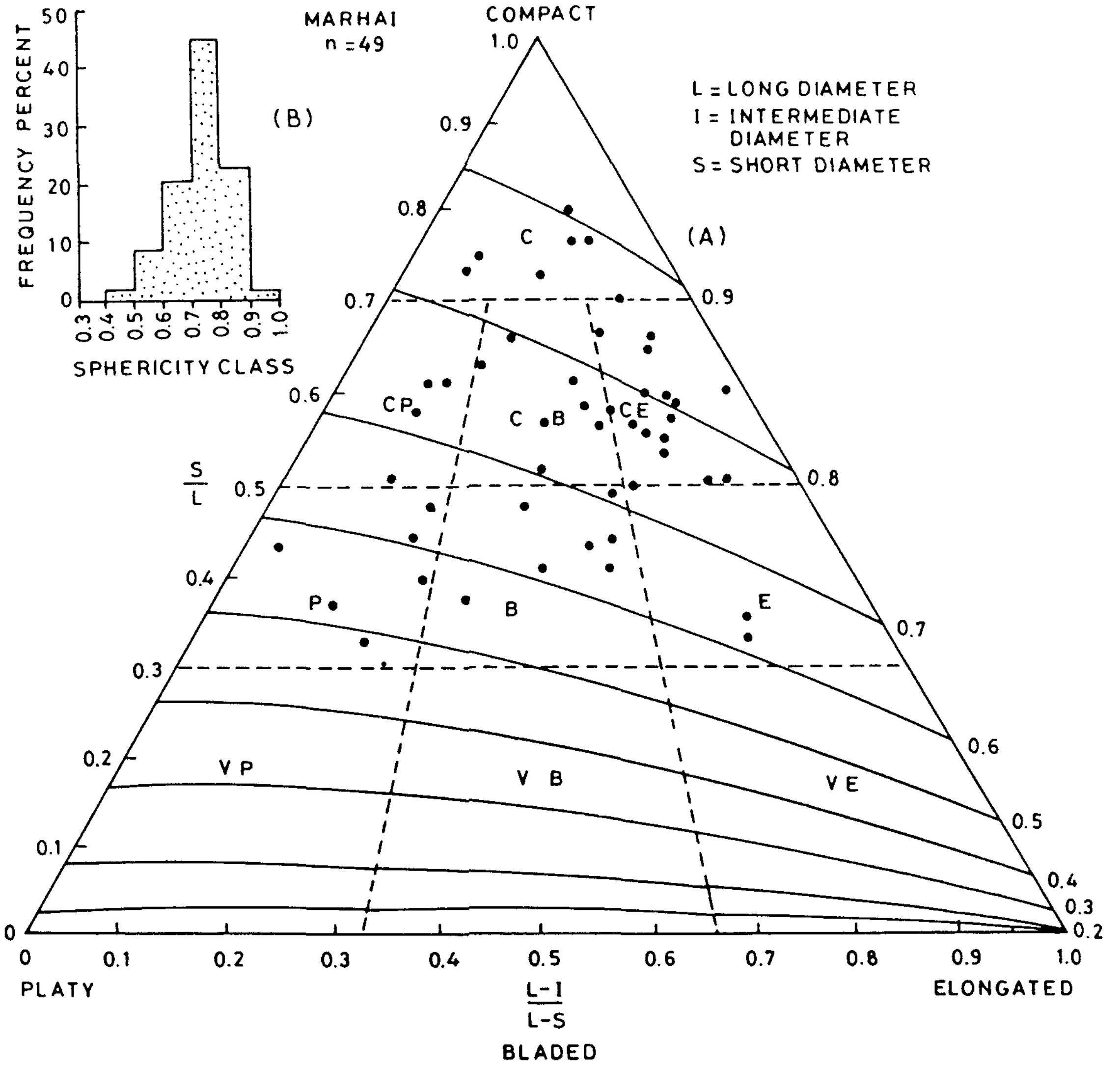

FIG.16.(A) TRIANGULAR PLOT FOR SHAPE ANALYSIS OF CLASTS IN UPPER DIAMICTITE IN MARHAI SECTION.

(B) HISTOGRAM SHOWING FREQUENCY DISTRIBUTION OF CLAST SPHERICITY FOR SAMPLE PLOTTED IN A.

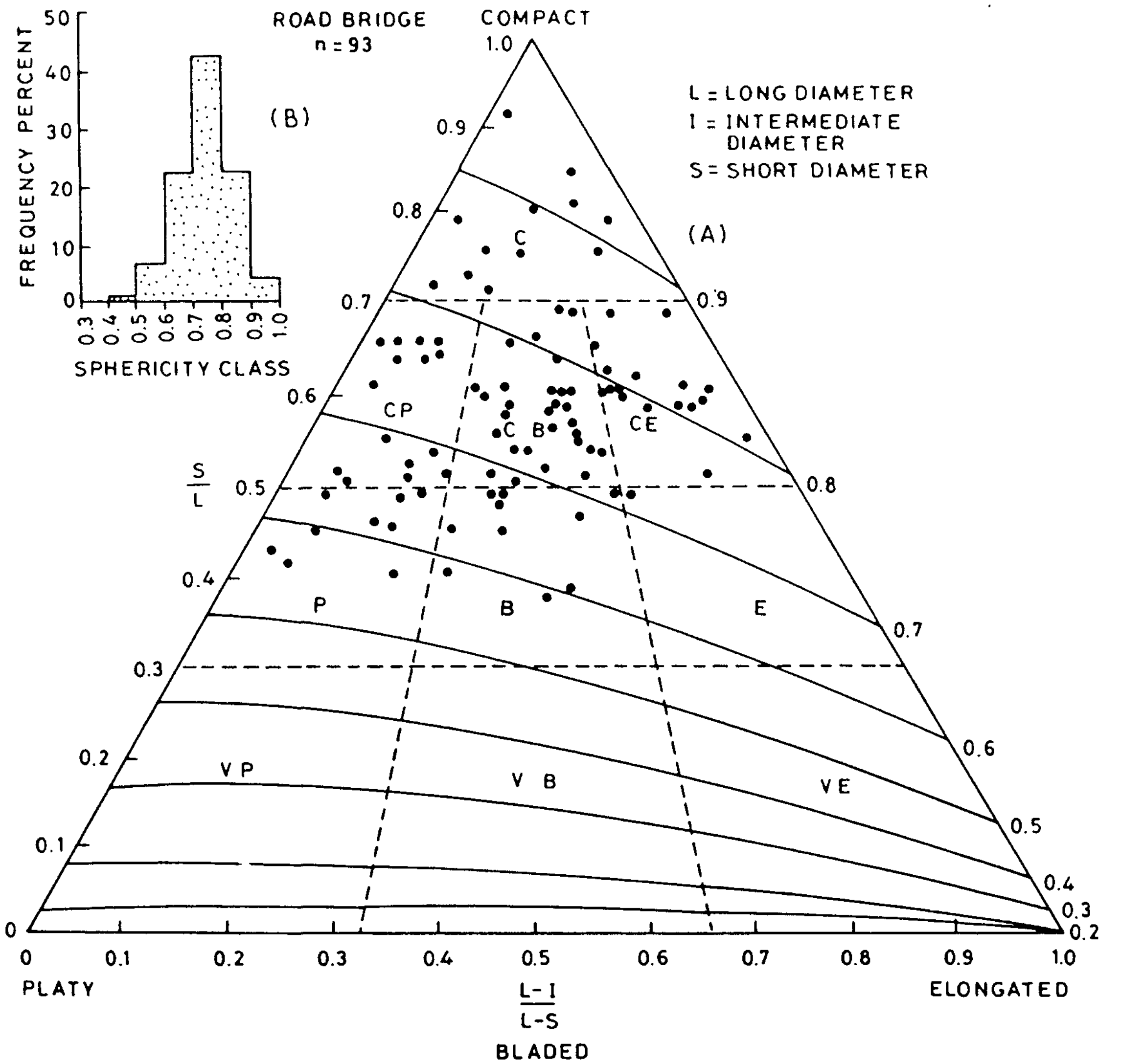

FIG.17.(A) TRIANGULAR PLOT FOR SHAPE ANALYSIS OF CLASTS IN UPPER DIAMICTITE IN ROAD BRIDGE SECTION.
(B) HISTOGRAM SHOWING FREQUENCY DISTRIBUTION OF CLAST SPHERICITY FOR SAMPLE PLOTTED IN A.

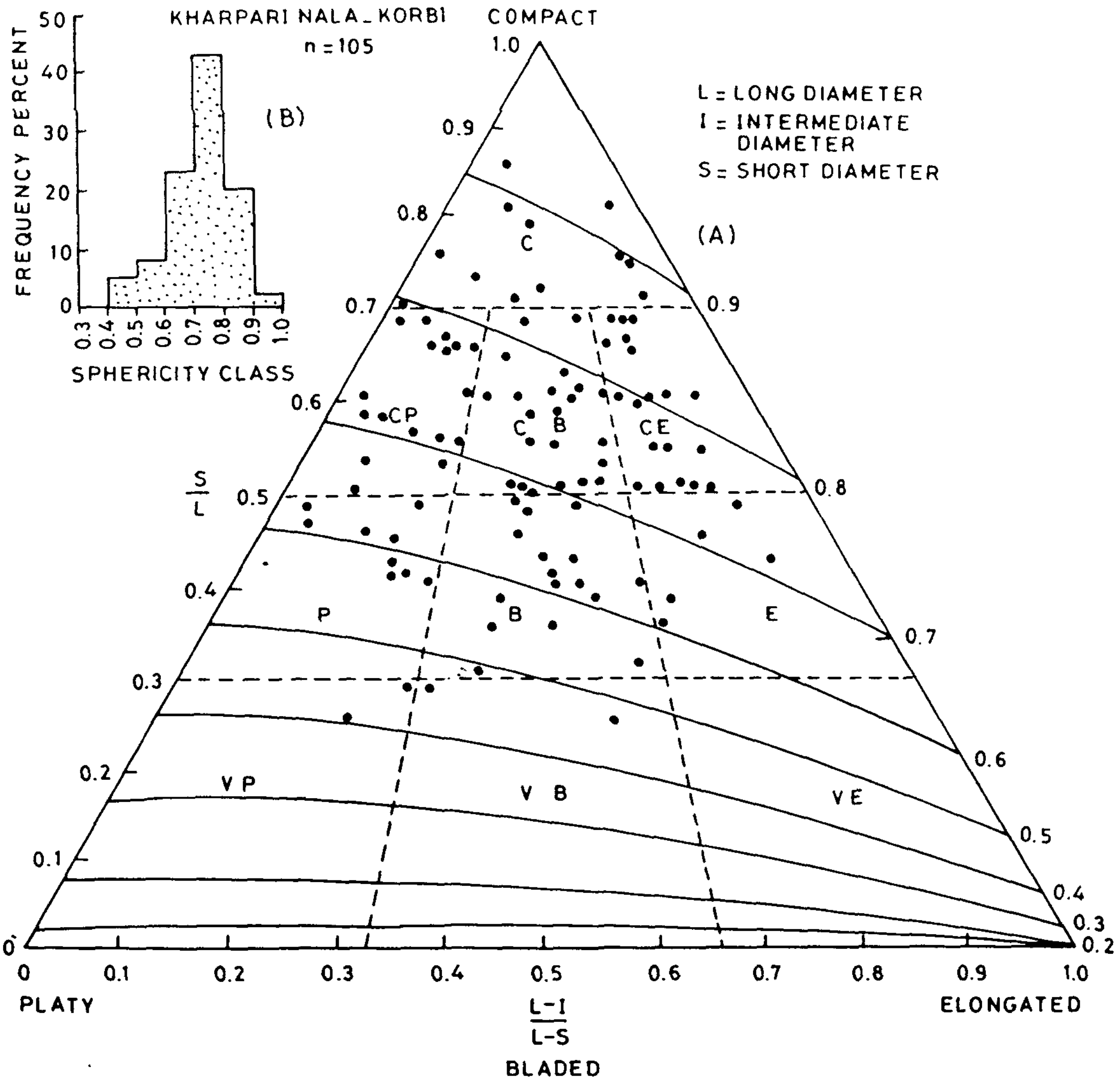

FIG.18.(A) TRIANGULAR PLOT FOR SHAPE ANALYSIS OF CLASTS IN UPPER DIAMICTITE IN KHARPARI NALA SECTION

(B) HISTOGRAM SHOWING FREQUENCY DISTRIBUTION OF CLAST SPHERICITY FOR SAMPLE PLOTTED IN A.

Table 21 : Shape Characteristics of Clasts in the Upper Diamictite.

Clast Form	Frequency (per cent) Marhai n = 49	Road Bridge n = 93	Kharpari Nala-Korbi n = 105	Average n = 247
Compact	14.28	12.90	11.42	12.55
Compact Platy	8.16	17.20	16.19	14.97
Compact Bladed	16.32	31.18	20.95	23.88
Compact Elongated	30.61	17.20	17.14	19.83
Platy	12.24	9.67	8.57	9.71
Bladed	14.28	10.75	17.14	14.17
Elongated	4.08	-	4.76	2.83
Very Platy	-	-	1.90	0.80
Very Bladed	-	1.07	1.90	1.21
Very Elongated	-	-	-	-

in clast shapes in the upper diamictite than the basal diamictite.

Table 22 lists the sphericity statistics of clasts of upper diamictite obtained from data plotted on triangular diagrams. The frequency distribution of the sphericity values are shown as histograms in Figures 16(B), 17(B) and 18(B). The frequency distributions of sphericity values are very uniform in all the samples inasmuch as the modal class lies in the 0.7 to 0.8 class and contains 43% to 45% of the total material.

3.4.6. Clast Lithology and Granular Variation

1378 clasts (102 from Marhai section, 560 from Road Bridge section and 716 from the Kharpari _nala_ - Korbi sections) were studied for understanding the lithological composition of the Upper Diamictite of the study area (Table 23).

Histogram in Figure 19 shows the percentage of embedded clasts of various lithologies in the Marhai section. Quartzite is the most abundant lithology and constitutes about 43% of total clasts by number, closely followed by granite and gneiss (31%) and red sandstones (about 20%). Thus, quartzites, granite-gneiss and sandstones together constitute 95% of the whole count. The remaining 5% comprise of clasts of slate and other low grade metamorphic rocks.

Table 22 : Sphericity characteristics of Clasts of Upper Diamictite.

Sphericity Class	Marhai (n = 49)			Road Bridge (n = 93)			Kharpari Nala-Korbi (n = 105)			Average (n = 247)		
	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)	Frequency Per cent	Mean Sphericity (Ma)	Standard Deviation (σ a)
1.0-0.9	2.04			4.30			1.90			2.83		
0.9-0.8	22.44			22.58			20.00			21.45		
0.8-0.7	44.89			43.01			42.85			43.31		
		0.733	0.099		0.742	0.098		0.751	0.111		0.731	0.103
0.7-0.6	20.40			22.58			22.85			22.26		
0.6-0.5	8.16			6.45			7.61			7.28		
0.5-0.4	2.04			1.07			4.76			2.83		
0.4-0.3												
0.3-0.2												

Table 23 : Results of clast count lithology-wise and size-wise of Upper Diamictite (in per cent by number)

Lithology / Size	>256 mm	256-128 mm	128-64 mm	64-32 mm	32-16 mm	16-8 mm	8-4 mm	Total Per cent
<u>Marhai Section</u>								
Quartzite	-	-	-	2.94	8.80	20.60	10.78	43.13
Granite and Gneiss	-	-	3.92	10.78	6.86	5.88	3.92	31.37
Sandstone	-	-	2.94	8.82	6.86	-	1.96	20.58
Phyllite/ Slate Schist	-	-	-	-	2.94	0.98	0.98	4.90
<u>Road Bridge Section</u>								
Quartzite	-	0.53	5.71	14.28	12.67	8.92	7.85	50.00
Granite and Gneiss	-	-	3.39	11.78	10.71	4.82	1.96	32.67
Sandstone	-	-	-	3.21	4.82	2.14	1.07	11.25
Limestone and Chert	-	-	-	0.53	1.96	1.42	1.25	5.17
Greenstone	-	-	-	-	-	0.35	0.53	0.88
<u>Kharpari Nala - Korbi Section</u>								
Quartzite	-	-	3.07	13.82	16.48	12.01	9.77	55.16
Granite and Gneiss	-	-	2.65	7.40	8.79	4.88	1.67	25.41
Sandstone	-	-	0.27	4.18	4.74	3.77	2.93	15.92
Limestone and Chert	-	-	-	0.27	1.25	1.11	0.41	3.07
Greenstone and Basalt	-	-	-	-	0.27	-	0.13	0.40

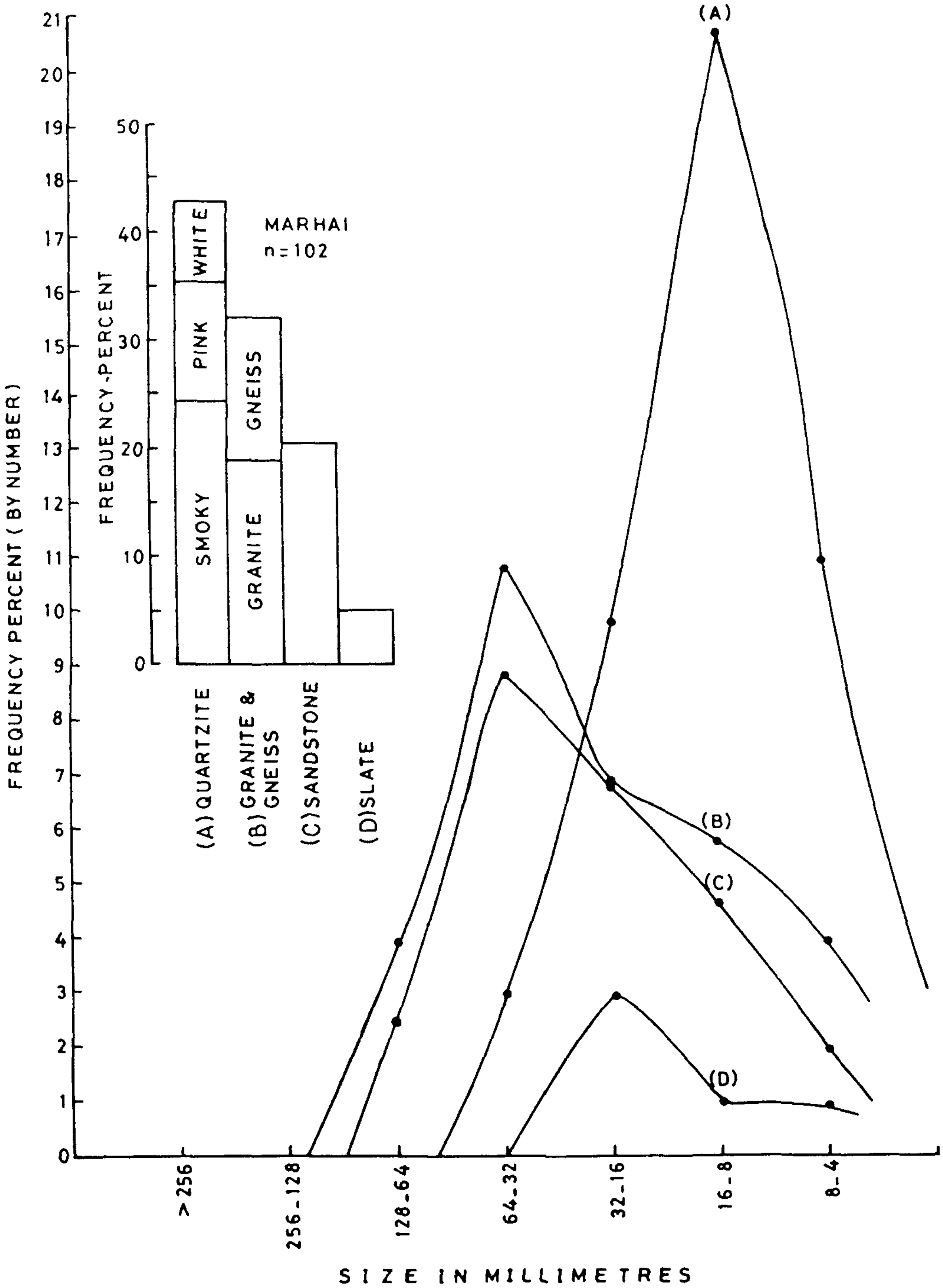

FIG.19. PLOT SHOWING GRANULAR VARIATION IN CLASTS OF UPPER DIAMICTITE IN MARHAI SECTION. INSET SHOWS GROSS COMPOSITION OF THE UPPER DIAMICTITE IN THE SAME SECTION.

Variation curves in Figure 19 show the relationship between clast composition and clast size in Marhai section. The most common lithology in the cobble grade (128-64 mm) is granite and gneiss followed closely by red sandstones. No other lithology occurs in this size. In the very coarse pebble size (64-32 mm) the same pattern is observed with the difference that quartzite pebbles also occur alongwith those named above. Quartzite is most dominant in the 16-8 mm grade (fine pebble size). It is the dominant lithology in coarse pebble and very fine pebble grades also. Fragments of slate are present in maximum number in the coarse pebble size, their percentage going down rapidly in the coarser and finer sizes.

560 clasts were counted in the road-bridge section. Histogram in Figure 20 shows that quartzite (50%), granite and gneiss (33%) constitute the most important lithology and together makeup 83% of clasts by number of the whole count in this section. The remaining lithologies present are sandstone (11%), limestone and chert (5%) and greenstone (1%).

Curves in Figure 20 show the granular variation in clast composition. Clasts of quartzite and granite-gneiss occur in this section as very coarse pebbles (64-32 mm). Similarly the red sandstone and limestone and chert clasts occur dominantly in coarse pebble grade (32-16 mm) while the clasts of greenstone and basalt occur as very pebbles (8-4 mm).

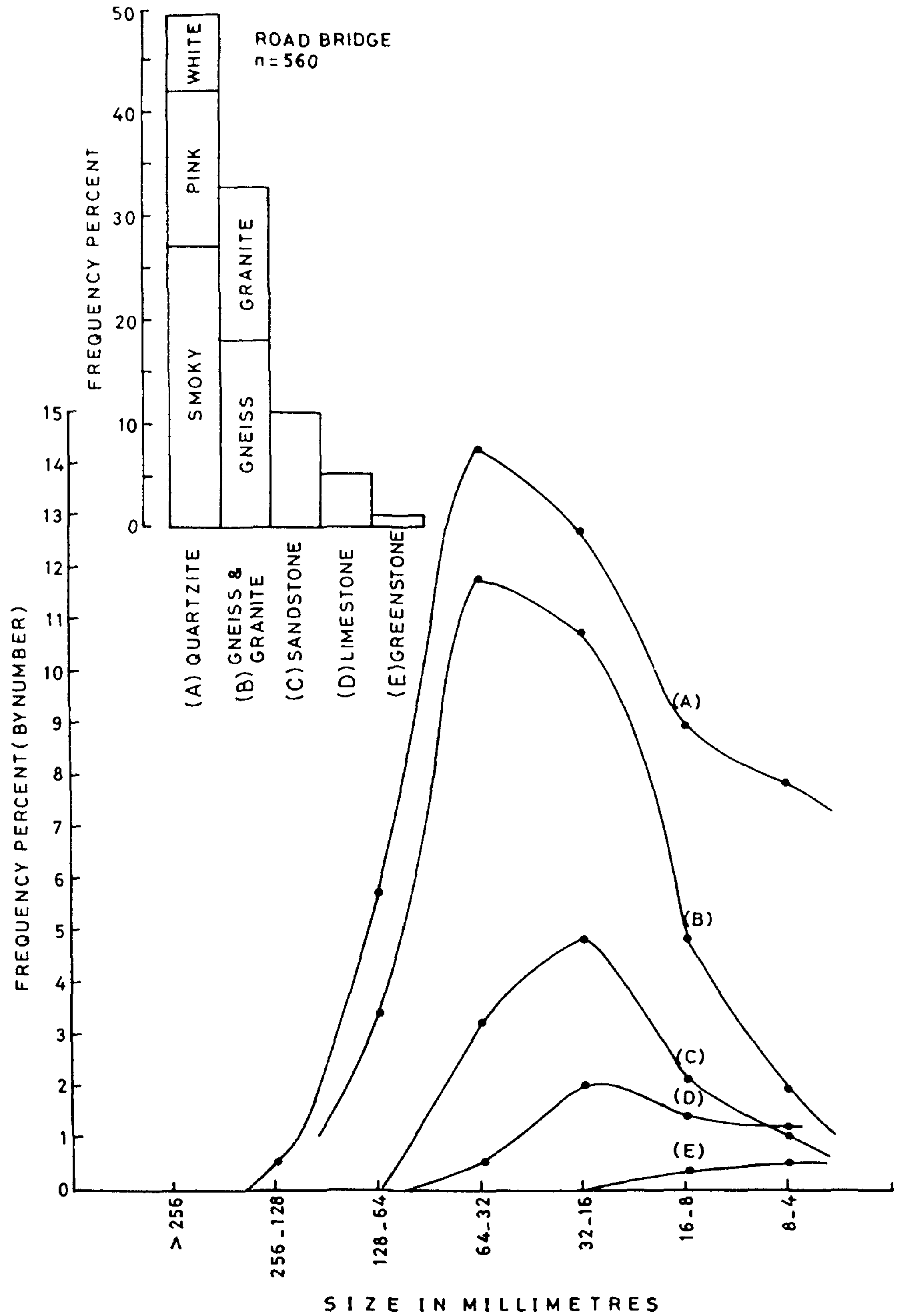

FIG.20.PLOT SHOWING GRANULAR VARIATION IN CLASTS OF UPPER DIAMICTITE IN ROAD BRIDGE SECTION. INSET SHOWS GROSS COMPOSITION OF THE UPPER DIAMICTITE IN THE SAME SECTION.

A study of 716 clasts from the Kharpari nala - Korbi section (Histogram in Figure 21) shows that the clasts of quartzite, constituting 55% of the whole count, is the most abundant lithology. Next in abundance are clasts of granite and gneiss (25%) followed by sandstone (about 16%) and limestone and chert and greenstone and basalt about 3% and 1% respectively.

Variation curves in Figure 21 show that the clasts of quartzite, granite and gneiss,and sandstone constitute 96% of the whole population of clasts in this section. Among them the quartzite clasts occur most abundantly as coarse pebble (32-16 mm) and their proportion gradually goes down towards the coarser as well as the finer sizes. The granite and gneiss,and sandstone clasts also occur most commonly as coarse pebbles (32-16 mm) and behave in the same manner as clasts of quartzite in other sizes. Among the remaining 6% the clasts of limestone and chert occur as coarse pebble (32-16 mm) and their proportion steeply goes down towards the finer sizes. The clasts of greenstone and basalt occur only in two size grades, that is, in coarse pebble (32-16 mm) and very fine pebble (8-4 mm) grades and are the least common lithologic types in this section.

3.4.7. Composition of Fine Fraction

In thin sections the fine fraction of the upper diamictite shows remarkable textural and compositional

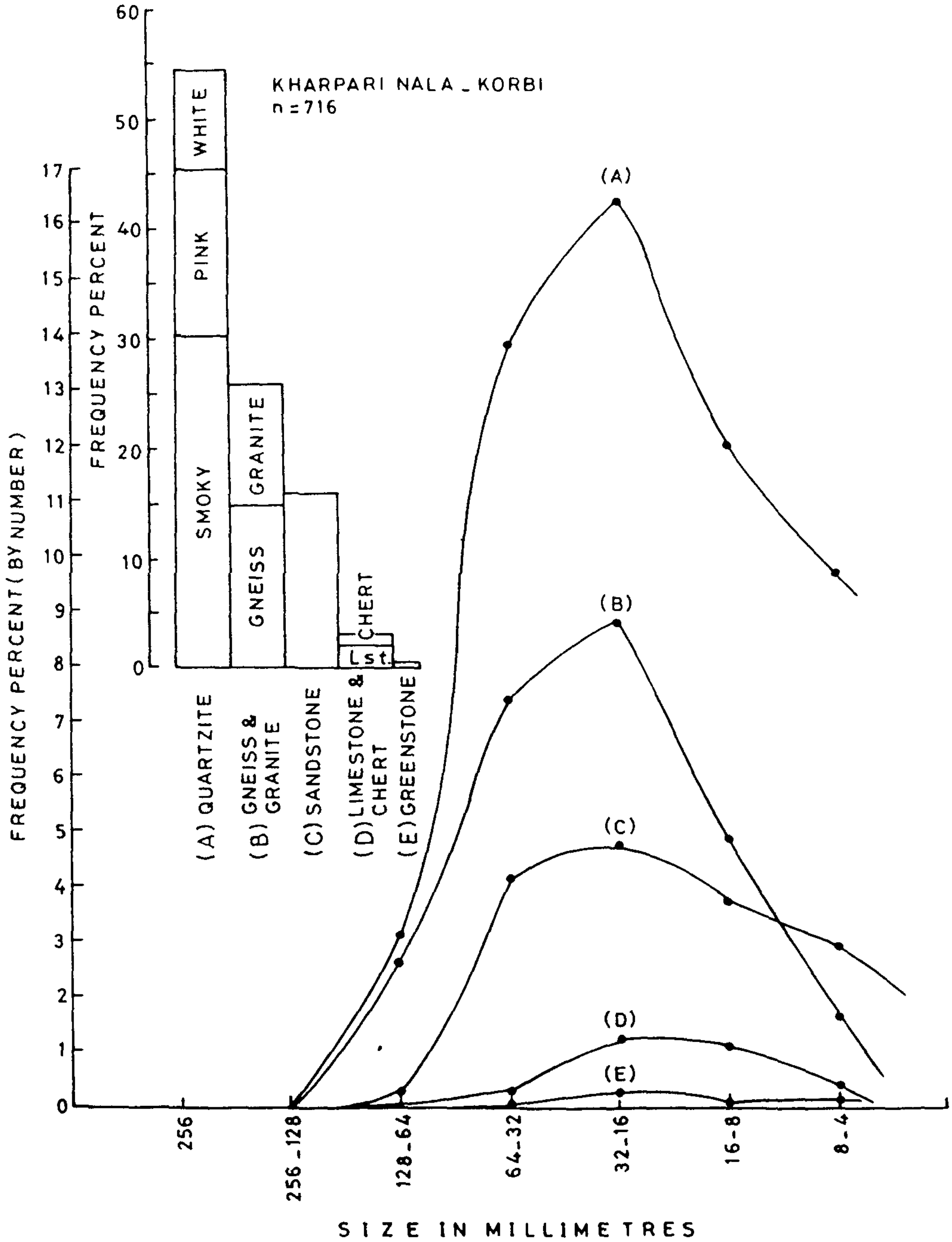

FIG.21.PLOT SHOWING GRANULAR VARIATION IN CLASTS OF UPPER DIAMICTITE IN KHARPARI NALA SECTION . INSET SHOWS GROSS COMPOSITION OF THE UPPER DIAMICTITE IN THE SAME SECTION .

uniformity and for this reason only fifteen representative thin sections, six each from Marhai and Kharpari nala - Korbi sections and three from the Road Bridge section were studied under the microscope for their compositional characteristics. Table 24 shows the average modal composition of the fine fraction of the upper diamictite at different localities in the study area, each column representing the average of three analyses.

The fine fraction of the upper diamictite is brown to buff in colour and in contrast to the same fraction of the basal diamictite, it is sandy. Further, the framework of this fraction is generally normal and the amount of detrital matrix is less than 15% by volume (Plate-13, Fig. 1).

Quartz : Quartz is by far the most dominant mineral constituting between 74% to a little more than 90% of the rock by volume. Most grains show straight extinction but a few exhibit slightly undulose extinction. A very wide range of roundness values is observed in the quartz grains (Plate-13, Figs. 1 & 2), the arithmetic mean roundness in the various samples ranging from 0.18 (sub-angular) to 0.34 (sub-rounded). On an average the grains are sub-rounded (Ma = 0.25). In some sections grains are characterized by their sharply angular nature but in all such cases it has been found that the angularity is apparent and not real, being due to wide spread corrosion by the opaline/carbonate cement (Plate-14, Figs. 2 & 3).

EXPLANATION OF PLATE XIII

Microphotographs of Matrix of Upper Diamictite

Figures 1, 2 & 3	The matrix of upper diamictite is moderately sorted and shows nearly normal framework. Grains of quartz are sub-angular to sub-rounded while grains of soft rock fragments are well rounded. Feldspar grains are generally altered and sub-rounded to rounded. Fragments of quartzite seen in the lower left hand side of Figure 3 is sub-angular and is much bigger than the surrounding quartz grains.

Fig. 1 (x 10)

Fig. 2 & 3 (ordinary light x 30)

PLATE XIII

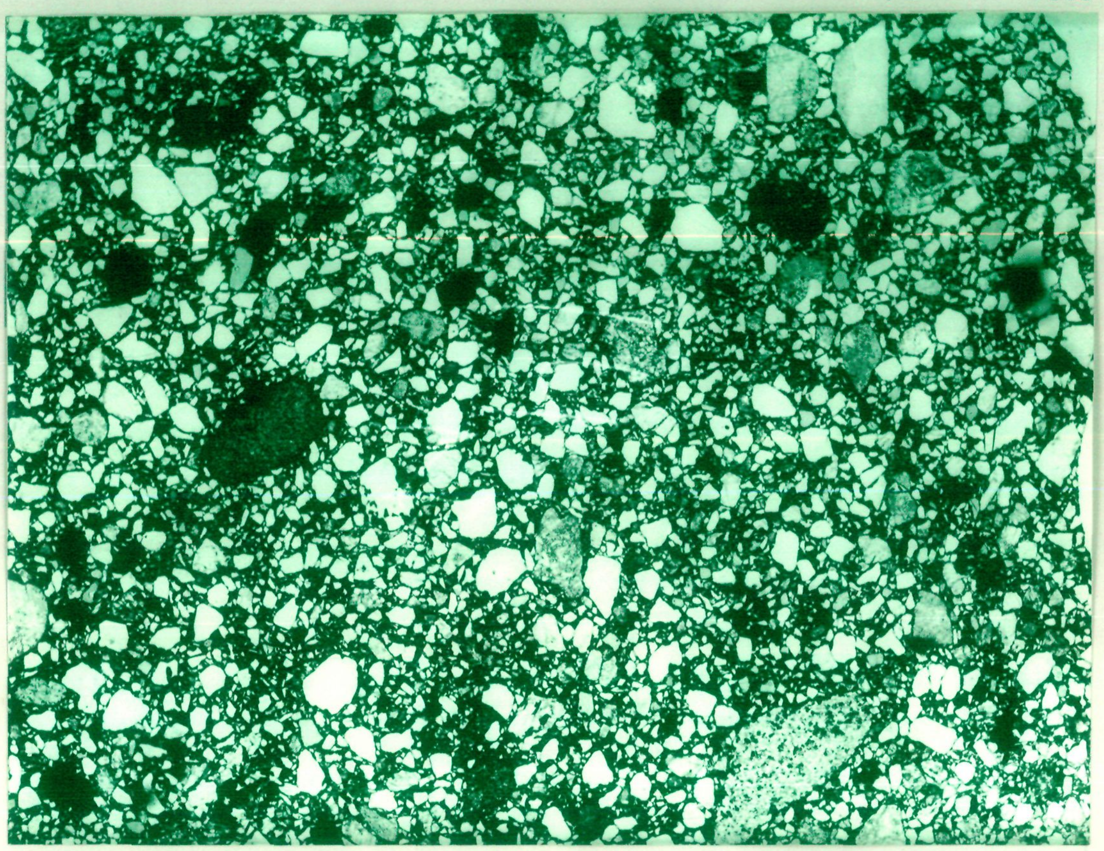

Fig.1 (x 10)

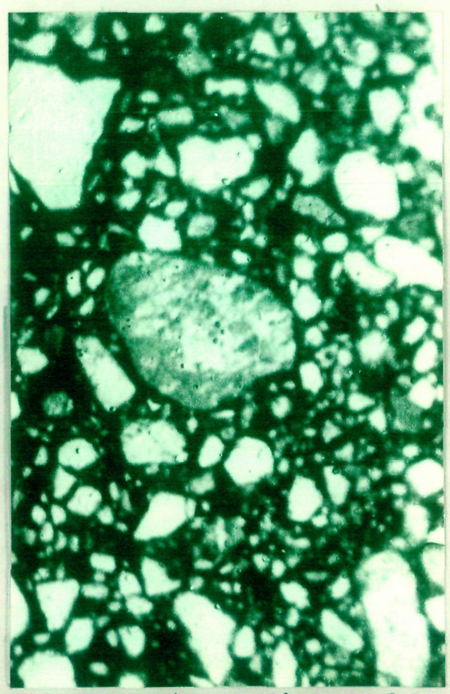

Fig. 2. Ordinary light x 30

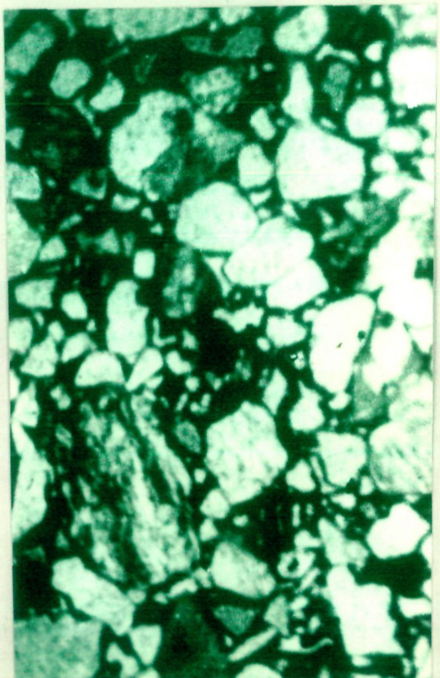

Fig. 3. Ordinary light x 30

Table 24 : Average Modal Composition of the Fine Fraction of the Upper Diamictite.

Locality	Marhai				Road Bridge		Kharpari Nala - Korbi			
Sample Numbers	1 (Average of 3)		2 (Average of 3)		1 (Average of 3)		1 (Average of 3)		2 (Average of 3	
Composition	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness (Ma)	Frequency Per cent	Arithmetic Mean Roundness
Quartz	75.00	0.34	74.33	0.18	77.33	0.31	85.83	0.24	86.66	0.20
Feldspar	3.33	0.36	9.00	0.21	9.00	0.35	2.66	2.26	2.33	0.23
[illegible] Fragments										
Quartzite/ Quartz Schist	-	-	3.00	0.22	2.66	0.36	2.66	0.45	3.00	0.26
Phyllite/ Slate	3.66	0.30	1.00	0.34	-	-	3.00	0.34	-	-
Granite/ Granitic Gneiss	-	-	1.66	0.23	1.33	0.40	1.50	-	0.33	0.4
Micritic Limestone	1.66	0.33	-	-	1.33	0.31	1.00	-	-	-
Chert	1.33	0.4[illegible]	0.66	0.31	0.66	0.31	1.33	0.40	0.66	0.5
Sandstone/ Siltstone	3.33	0.24	0.66	0.15	2.33	0.43	-	-	-	-
[illegible]	12.32	0.34	8.65	0.[illegible]	[illegible].33	0.36	1.99	0.44	7.00	0.2

Feldspar : Feldspar occurs as sub-angular to rounded, altered to fresh grains and constitute 2.33% to 9% of the rock by volume (Plate-13, Fig. 2 and Plate-14, Fig. 3). Both the potash and plagioclase varieties are present.

In most of the specimens feldspar occurs in two sizes - big and small. The bigger grains of feldspar are generally sub-rounded to rounded and comprise of remarkably fresh grains of microcline. The smaller grains are generally fresh and consist of angular to sub-rounded plagioclase. The highly altered grains are often crushed between the harder grains of quartz and thus contribute towards the formation of matrix in the rock.

Rock Fragments : Rock fragments put together constitute 4% to 10% of the rock by volume and consist of varied lithology namely quartzite/quartz-schist, phyllite/slate, granite/granite-gneiss, micritic limestone, chert and sandstone/siltstone.

The soft rock fragments such as phyllite and slates, are often crushed and squeezed between the harder grains and at places they can hardly be distinguished from the detrital matrix. Indeed, there is evidence that a considerable portion of the detrital matrix has been produced as a result of crushing of phyllite and slate fragments.

Quartzite fragments (2.66%- 3.00%) are bigger in size than the other fragments present and are generally sub-angular to sub-rounded (Plate-13, Fig. 3). The individual quartz grains

EXPLANATION OF PLATE XIV

Figure 1	Matrix of upper diamictite showing moderate sorting and normal framework. The large grains of calcareous siltstone is well rounded while grains of quartz are generally angular to sub-rounded. Feldspar grains are altered and sub-rounded.
	x 15
Figures 2 & 3	Large scale replacement of quartz grains by sparry calcite cement resulting in a disrupted framework. In figure 2 the grains of feldspar show no effects of corrosion. In figure 3, the replacement of quartz grain is so large that a disrupted framework is seen in patches.
	Fig. 2 (Ordinary light x 75)
	Fig. 3 (Cross-nicol x 30)

PLATE XIV

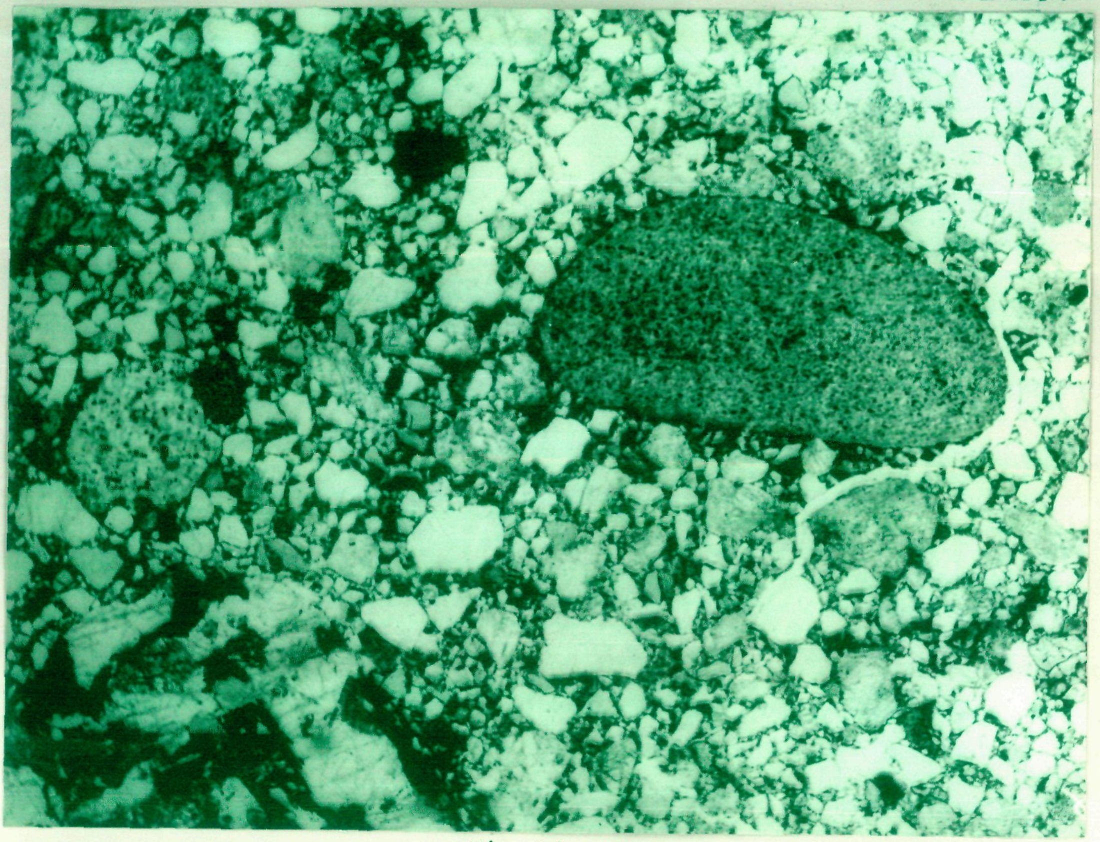

Fig. 1 (x 15)

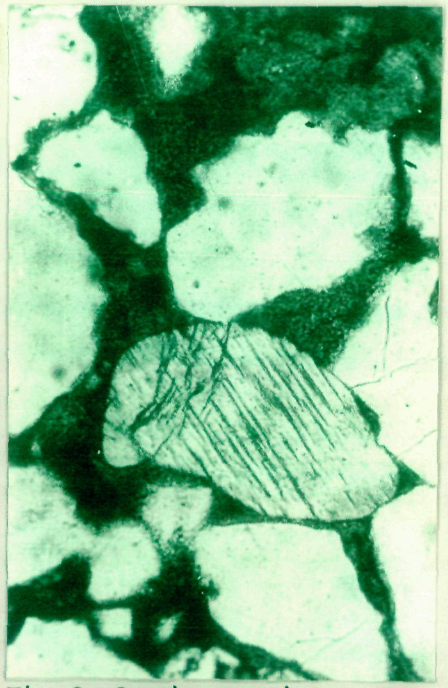

Fig. 2. Ordinary light x 75

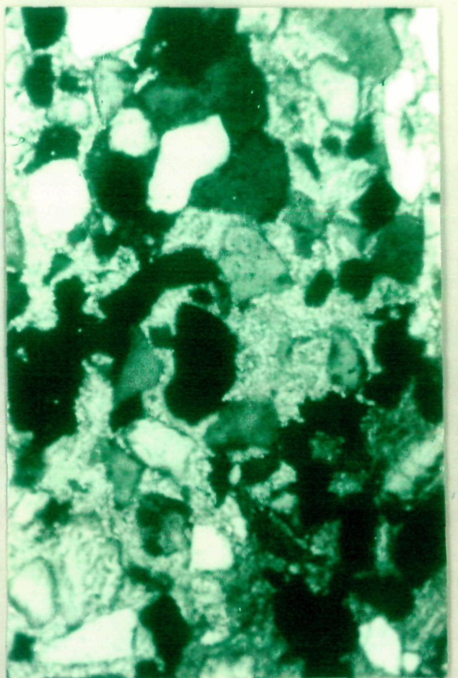

Fig. 3. x-nicol x 30

present in the quartzite fragments show wavy extinction and are more or less of the same size as the single quartz grain present in the rock. It is very possible that some of the quartz grains present in the matrix might have been derived from the break up of the bigger quartzite fragments.

Fragments of granite and gneiss are present to the extent of 0.33%to 1.66% of the rock by volume. The quartz and feldspar grains within these fragments are more or less of the same size as of the medium sized quartz and feldspar grains occurring separately in the rock. This feature shows that the quartz and feldspar grains of the fine fraction of this diamictite may have been derived by the crushing of granite and gneiss fragments.

Sedimentary rock fragments (micritic limestone, chert and sandstone/siltstone) occur to the extent of 1% to 6% of the rock by volume. Fragments of micritic limestone and calcareous siltstone are generally big in size and occur as rounded to well rounded grains (Plate-14, Fig. 1). Chert grains are generally sub-rounded to rounded and occur in smaller size. Sub-angular to rounded fragments of calcareous quartz-arenite are also seen. The individual quartz grains showing well defined authigenic overgrowths.

As mentioned earlier the framework of the fine fraction of the upper diamictite is generally normal. However, in some specimens the amount of matrix present varies from 12%to 18% by volume and the framework of the rock appears disrupted.

It has been mentioned earlier that there is evidence to show that almost all types of rock fragments show crushing to large extent. Altered grains of feldspars and soft rock fragments such as micritic limestone, slate and chloritic phyllite, when crushed become indistinguishable from the detrital matrix and tend to produce disrupted framework. Although it is not possible to estimate the ratio of primary to secondary matrix in the rock, it can be safely inferred that much of the matrix is of secondary origin and has been produced by the crushing of the soft rock fragments.

The fine fraction of the upper diamictite differs from that of the basal diamictite in the following important respects.

(i) It contains a larger quantity of quartz and feldspars in contrast to the basal diamictite.

(ii) The quantity of rock fragments is much smaller in the upper diamictite as compared to the basal diamictite.

(iii) Fragments of sandstone/siltstone are absent in the basal diamictite but are present in the upper diamictite.

(iv) The framework of the fine fraction of the upper diamictite is generally normal in contrast to the generally disrupted nature of the framework of the fine fraction of the basal diamictite.

The modal composition of the fine fraction of the upper diamictite is plotted in Figure 12. Since the amount of matrix present is less than 15%, they are termed 'arenites'. Four out of five samples have the composition of sub-litharenite, while one is sub-arkosic in composition.

3.4.8. Heavy Minerals

Heavy minerals were extracted from 9 selected samples of the matrix of Upper diamictite, three samples coming from each of the three sections studied. The data on the frequency of their occurrence appear in Table 25.

Their characters are similar to those described under section 3.3.8. and shown in Plate 12.

3.5. SANDSTONES

3.5.1. Mechanical Composition

In the hand specimen and thin sections the sandstones of the area of investigation show remarkable uniformity of textural and compositional characters and can be distinguished from each other only on the basis of their bedding characters and sedimentary structures. Thus, in view of this uniformity, out of 240 samples of sandstones collected during field work, only 48 samples were selected for preparing thin sections in

Table 25 : Average Heavy Mineral Composition of Fine Fraction of Upper Diamictite
(Per cent by number)

White Garnet	Pink Garnet	Epidote	Tourm-aline	Zircon	Musco-vite	Rutile	Titanite	Biotite	Apatite	Opaques
Marhai										
86.65	6.84	2.32	0.23	0.34	0.34	0.23	-	-	0.34	2.66
Road Bridge										
81.51	11.27	2.44	0.23	0.81	0.81	-	-	-	-	2.90
Kharpari Nala - Korbi										
84.05	7.72	3.26	1.18	0.59	0.39	-	-	-	0.19	2.57
Average										
84.07	8.56	2.70	0.58	0.58	0.51	0.07	-	-	0.18	2.70

such a way that they covered almost the entire area and were representative in character. Of these, 20 each come from the massive and cross-stratified sandstone facies and 8 from the inter-bedded facies. Table 26 shows the result of thin section size analyses, each column representing the average of 4 thin section size analyses.

The size frequency distribution in massive sandstone is represented as histograms in Figure 22, and as cumulative curves in Figure 23. It is observed that the frequency distribution is trimodal in one sample, bimodal in two and unimodal in two samples. The number of half-phi classes containing more than 5% of the material is 5 to 6 thus indicating moderate sorting. The position of the primary mode in the bimodal/trimodal samples lies in 3.0 - 3.5 Ø class (very fine sand) in three samples and in 2.5 - 3.0 Ø class (fine sand) in two samples. The position of secondary mode in these samples is more variable and falls in the medium silt, coarse silt and very fine sand classes. In the two unimodal samples the mode lies in the 2.5 - 3.0 Ø class (fine sand) and 3.0 - 3.5 Ø class (very fine sand).

Table 27 shows the characteristics of the size frequency distribution in the samples under study. In all samples of the massive sandstone, the graphic mean size (Mz) varies from 3.18 to 3.94 (very fine sand). Samples showing unimodal size frequency distribution are moderately well sorted while out of the three samples showing bimodal/trimodal distribution, two are moderately

Table 26 : Mechanical Composition of Talchir Sandstones(Frequency by number)

Sandstone Facies		Massive Sandstone					Cross-stratified Sandstone					Inter-bedded Sandstone	
Size Grades mm scale	Ø scale	1	2	3	4	5	1	2	3	4	5	1	2
0.71-0.50	0.5-1.0	0.41	-	-	-	-	-	-	-	1.00	-	-	-
0.50-0.35	1.0-1.5	0.41	-	-	-	-	-	-	0.66	4.33	-	-	-
0.35-0.25	1.5-2.0	2.88	-	1.66	4.00	-	-	1.33	4.00	19.66	1.33	0.33	-
0.25-0.17	2.0-2.5	17.28	1.33	17.00	9.33	0.33	0.66	2.00	15.33	27.66	18.66	2.66	0.66
0.17-0.12	2.5-3.0	22.63	13.70	32.33	20.00	11.00	10.00	3.33	29.33	22.00	46.00	18.66	4.00
0.12-0.08	3.0-3.5	17.69	29.00	25.00	38.66	36.33	34.00	23.33	34.66	16.66	28.66	31.00	11.00
0.08-0.62	3.5-4.0	20.16	16.71	12.33	10.00	24.00	25.33	25.33	12.00	5.33	4.00	21.00	23.66
0.62-0.04	4.0-4.5	7.82	13.00	10.33	16.00	20.66	22.00	38.66	4.00	2.33	1.33	17.66	39.33
0.04-0.31	4.5-5.0	10.29	12.00	1.33	1.33	7.66	7.33	6.00	-	1.00	-	8.00	17.00
0.31-0.15	5.0-5.5	0.41	14.33	-	-	-	0.66	0.66	-	-	-	0.66	4.33

Note :- Each column represents the average of four thin section size analyses.

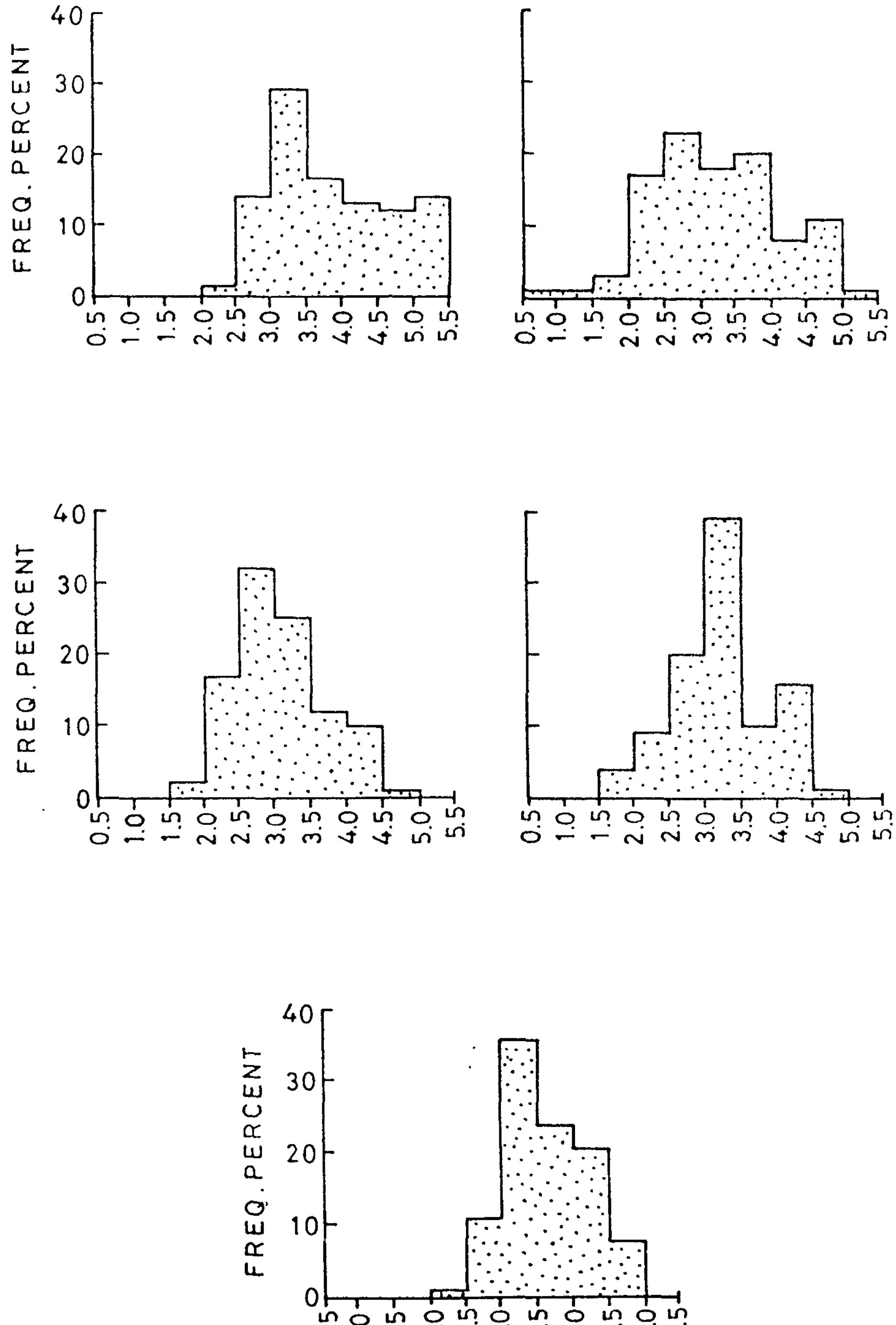

FIG.22. HISTOGRAMS SHOWING SIZE FREQUENCY DISTRIBUTION OF MASSIVE SANDSTONE.

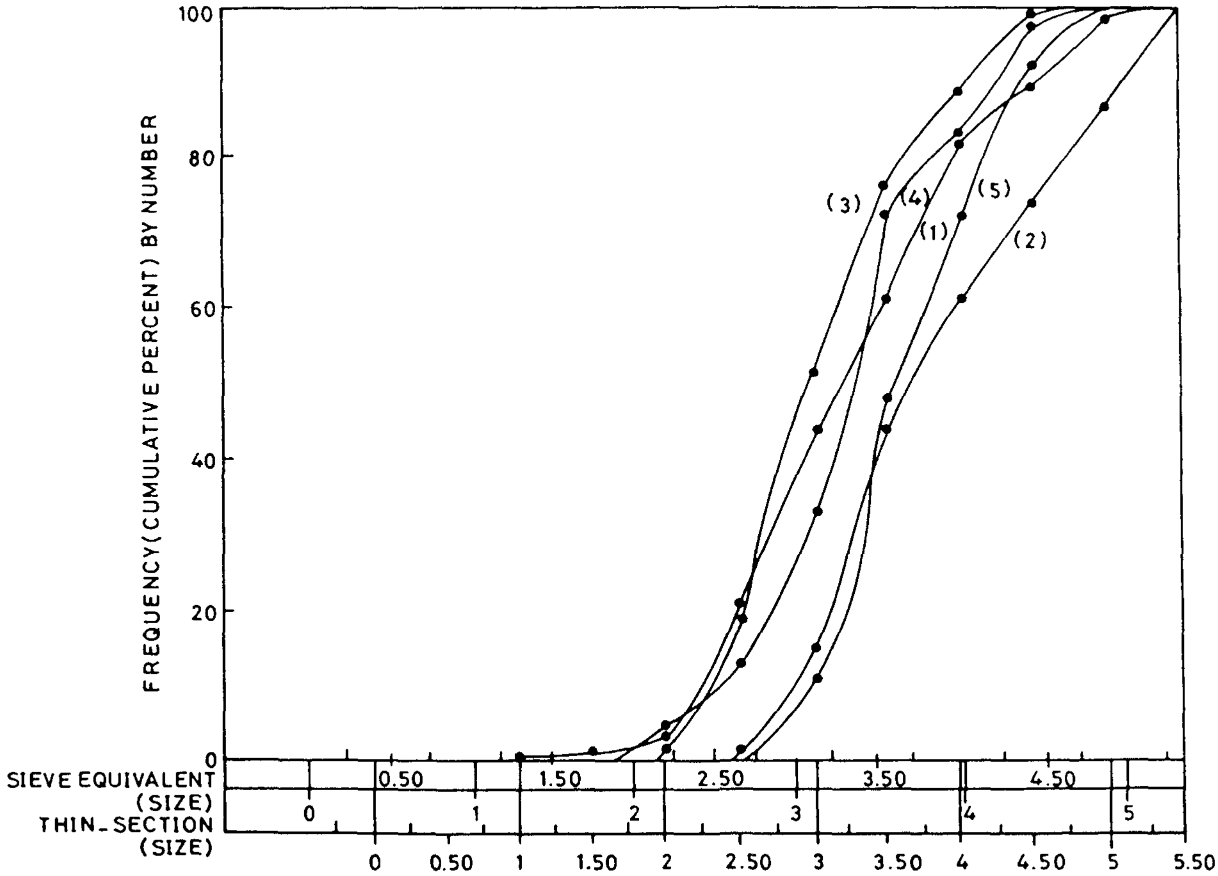

FIG.23. CUMULATIVE CURVES SHOWING SIZE FREQUENCY DISTRIBUTION OF MASSIVE SANDSTONE.

Table 27 : Characteristics of size frequency distribution of sandstones.

Sample Number	Graphic Mean (Mz)	Inclusive Graphic Standard Deviation (σ_1)	Inclusive Graphic Skewness (SK_1)	Graphic Kurtosis (KG)	Uni/Poly Modal
Massive Sandstone					
1.	3.34 (Very fine sand)	0.78 (Moderately sorted)	0.11 (Fine skewed)	0.68 (Platy-kurtic)	Bimodal
2.	3.94 (Very fine sand)	0.82 (Moderately sorted)	0.[illegible]7 (Fine skewed)	0.80 (Platy-kurtic)	Trimodal
[illegible]	[illegible]18 (Very fine sand)	0.61 (Moderately well sorted)	0.[illegible]2 (Fine skewed)	1.01 (Meso-kurtic)	Unimodal
4	3.3[illegible] (very fine sand)	0.64 (Moderately well sorted)	0.01 (Near symmetrical)	1.14 (Lepto-kurtic)	Bimodal
[illegible]	[illegible] (Very fine sand)	0.51 (Moderately well sorted)	0.17 (Fine skewed)	0.96 (Meso-kurtic)	Unimodal
[illegible] Stratified Sandstone					
1.	3.75 (Very fine sand)	0.53 (Moderately well sorted)	0.19 (Fine skewed)	1.12 (Lepto-kurtic)	Unimodal
2.	3.85 (Very fine sand)	0.50 (Moderately well sorted)	0.03 (Near symmetrical)	0.90 (Meso-kurtic)	Unimodal
[illegible]	[illegible].08 (Very fine sand)	0.51 (Moderately well sorted)	0.05 (Near symmetrical)	1.04 (Meso-kurtic)	Unimodal
[illegible].	[illegible].[illegible]4 (Fine sand)	0.84 (Moderately sorted)	-0.02 (Near symmetrical)	1.12 (Lepto-kurtic)	Unimodal
[illegible]	[illegible].98 (Fine sand)	0.39 (Well sorted)	-0.01 (Near symmetrical)	1.06 (Meso-kurtic)	Unimodal
[illegible]bedded Siltstone/Sandstone					
[illegible]	[illegible].60 (Very fine sand)	0.63 (Moderately well sorted)	0.21 (Fine skewed)	0.89 (Platy-kurtic)	Unimodal
.	4.08 (Coarse silt)	0.51 (Moderately well sorted	0.11 (Fine skewed)	1.28 (Lepto-kurtic)	Unimodal

sorted and one is moderately well sorted. Four samples (Nos. 1, 2, 3 and 5) are fine skewed while one (No. 4) shows near symmetrical size frequency distribution. Various samples range from platy-kurtic to lepto-kurtic indicating that the peakedness of the frequency distribution is not high.

Figure 24 shows the histograms representing the size frequency distribution of five samples (each sample being the average of 4 thin section mechanical analyses) of cross-stratified sandstones. In all cases the frequency distribution is unimodal and the number of half-phi size classes containing more than 5 per cent of the material ranges from 3 to 5. The size frequency distribution of this facies is shown as cumulative curves in Figure 25 and the statistical parameters calculated there from, are given in Table 27. The cross-stratified sandstones are very fine to fine grained (Mz ranging from 2.54 Ø to 3.85 Ø). Three samples out of five are moderately well sorted while one is well sorted and another is moderately sorted. On the whole this sandstone group is better sorted than the one described above. Further, the frequency distribution is near symmetrical in four out of five samples and fine skewed in only one case in contrast to the massive sandstones. Further, in comparison to the massive sandstones, the peakedness of the frequency distribution is more prominent, the KG values ranging from 0.90 to 1.21 (meso-kurtic to lepto-kurtic).

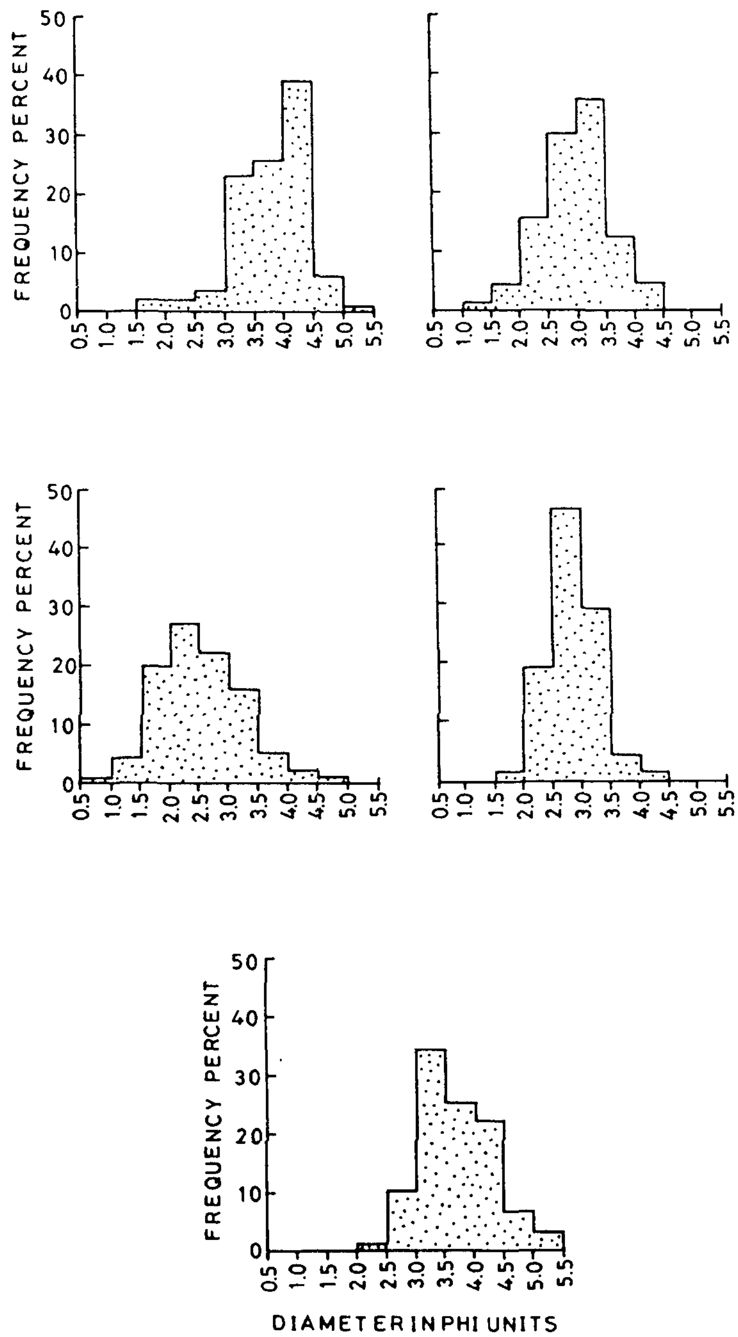

FIG. 24. HISTOGRAMS SHOWING SIZE FREQUENCY DISTRIBUTION OF CROSS-STRATIFIED SANDSTONE.

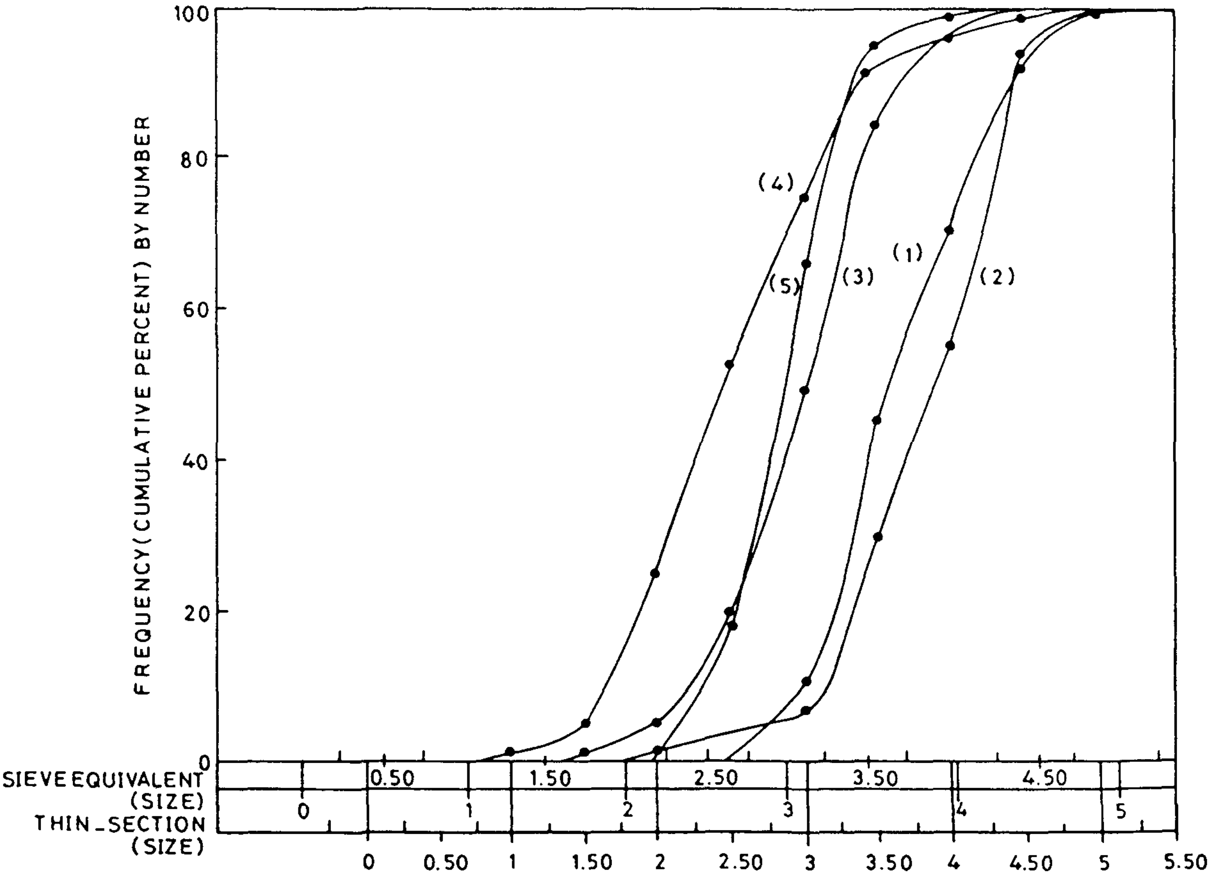

FIG.25. CUMULATIVE CURVES SHOWING SIZE FREQUENCY DISTRIBUTION OF CROSS-STRATIFIED SANDSTONE.

The size frequency distribution data of inter-bedded sandstone facies is shown as histograms in Figure 26. The modal class in one sample lies in the 3.0 - 3.5 Ø class (very fine sand) and in the other in 4.0 to 4.5 Ø class (coarse silt). The size data are spread over 4 to 5 half-phi classes. Both samples show unimodal size frequency distribution.

Figure 27 shows the same data represented as ,cumulative curves and table 27 lists the corresponding statistical parameters. Both samples are moderately well sorted and fine skewed. One sample is platy-kurtic and the other is lepto-kurtic. In a general way the siltstones/sandstones inter-bedded with shales show textural characters inbetween the cross-stratified sandstones and massive sandstones.

3.5.2. Roundness Characteristics

Roundness studies have been made on the same samples for which the size analysis was done. Table 28 shows the frequency distribution of roundness values of grains in massive sandstone, cross-stratified sandstone and inter-bedded siltstone/sandstone. Each column represents the average of 4 samples.

The roundness data are graphically represented as histograms in Figure 28. It is noteworthy that there is

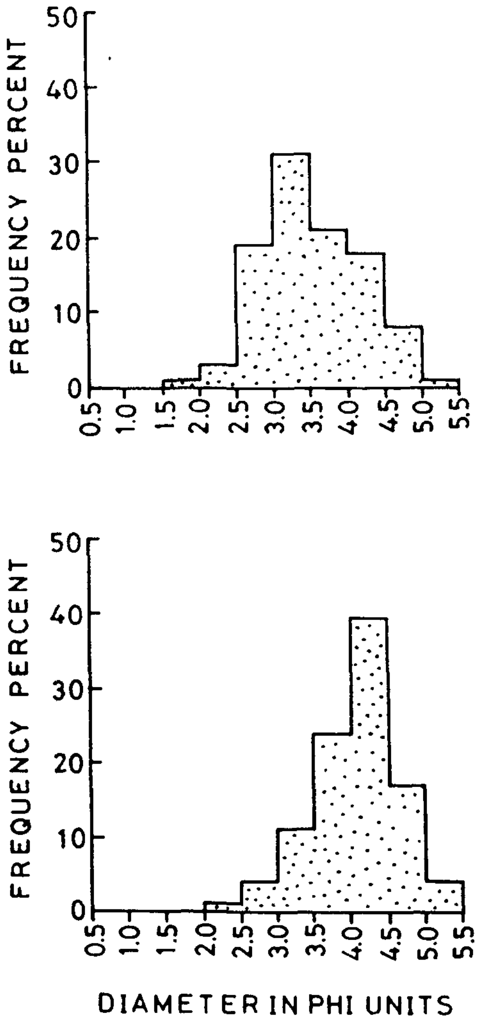

FIG.26. HISTOGRAMS SHOWING SIZE FREQUENCY DISTRIBUTION OF INTERBEDDED SILTSTONE / FINE SANDSTONE .

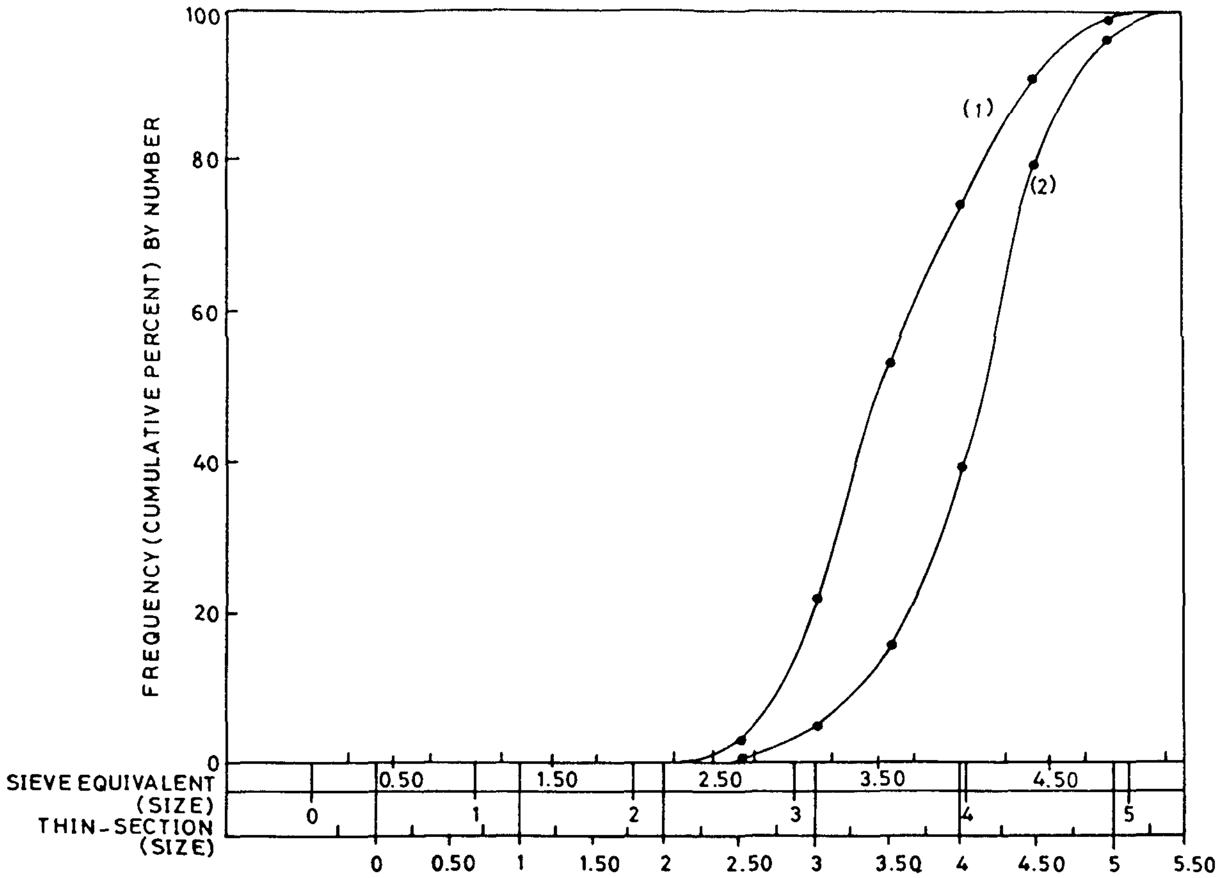

FIG.27. CUMULATIVE CURVES SHOWING SIZE FREQUENCY DISTRIBUTION OF INTER-BEDDED SHALE AND SILTSTONE / SANDSTONE.

Table 28 : Roundness frequency distribution data of grains in different sandstone facies

Sandstone Facies	Massive sandstone					Cross-stratified sandstone					Inter-bedded sandstone	
Roundness Class	1	2	3	4	5	1	2	3	4	5	1	2
0.00-0.15 (Angular)	2.05	2.33	1.66	3.66	4.33	4.66	5.33	3.66	5.33	4.33	6.66	9.66
0.15-0.25 (Sub-angular)	32.92	23.00	27.33	33.00	36.33	35.33	30.66	20.00	23.00	20.66	23.00	33.00
0.25-0.40 (Sub-rounded)	56.37	49.33	57.33	50.66	52.66	56.00	49.33	60.66	59.66	61.66	51.33	41.66
0.40-0.60 (Rounded)	8.23	21.00	13.33	10.33	6.33	4.00	11.66	14.33	10.33	12.33	17.66	15.66
0.60-1.00 (Well-rounded)	0.41	4.33	0.33	2.33	0.33	-	3.00	1.33	0.83	1.00	1.33	-

Note :- Each column represents the average of 4 analyses.

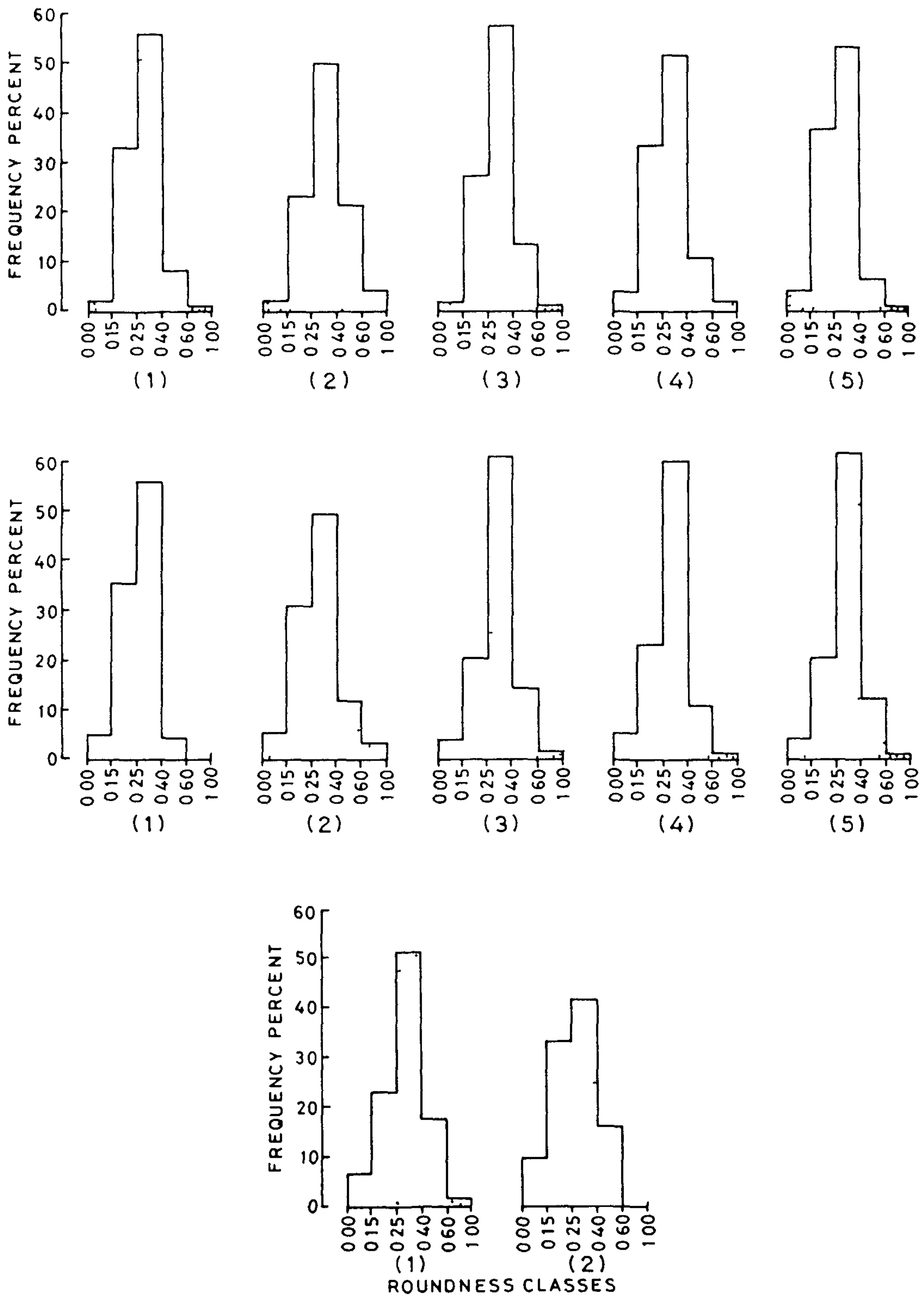

FIG 28 HISTOGRAMS SHOWING THE FREQUENCY DISTRIBUTION OF ROUNDNESS VALUES IN SANDSTONES

remarkable similarity in all histograms meaning thereby that the roundness characteristics of samples from the different sandstone facies are very much the same. Thus, in all cases the modal roundness falls in the sub-rounded class, the number of roundness classes containing more than 5 per cent data are 3 to 4 and all samples are skewed towards lower roundness values. However, there appear to be some differences between sandstones of different facies in respect of peakedness of the roundness frequency distribution. In cross-stratified sandstones, the amount of material in the modal class, which is a measure of peakedness, varies from 49.33% - 61.66% (average 57.46%) while in massive sandstones and in inter-bedded sandstones it varies from 49.33 to 57.33% (average 53.15%) and 41.66% to 51.33% (average 46.5%) respectively.

Table 29 lists the roundness statistics of the various samples in regard to arithmetic mean roundness (Ma) and standard deviation (σa). In massive sandstones Ma values range from 0.34 to 0.40 (average 0.37), in cross-stratified sandstones from 0.33 to 0.38 (average 0.36) and in inter-bedded sandstones from 0.34 to 0.38 (average 0.36). Values of standard deviation in all samples analysed are about the same order of magnitude.

Table 29 : Roundness statistics of sandstone.

	Arithmetic Mean Roundness (Ma)	Standard Deviation (σa)
Massive sandstone		
1	0.35	0.11
2	0.40	0.16
3	0.37	0.12
4	0.36	0.14
5	0.34	0.11
Cross-stratified sandstone		
1	0.33	0.11
2	0.36	0.15
3	0.38	0.13
4	0.37	0.14
5	0.37	0.13
Inter-bedded sandstone		
1	0.38	0.15
2	0.34	0.15

3.5.3. Composition of Sandstones

Fortyeight thin sections of sandstones, twenty each from the massive and cross-stratified facies and eight from the inter-bedded shale and siltstone/sandstone facies, were studied under the petrological microscope for their petrographic characters. The constituents of four thin sections of sandstones from neighbouring localities were averaged to give a more representative picture and to minimise the effects of local variations in the modal composition of the sandstones (Table 30).

The sandstones were classified according to the scheme proposed by Casshyap (1967, 1969). Since these rocks contain less than 15 per cent matrix (including secondary matrix generated by the crushing of the soft rock fragments) the sandstones are termed as 'arenites' in contrast to the 'wackes' which contain more than 15 per cent matrix. The three end numbers in this classification, namely, quartz resistates (quartz, fragments of quartzite, quartz schist and chert), feldspars, and labile rock fragments (including heavies derived therefrom) were recalculated to 100 per cent and plotted in the triangular diagram (Fig. 29). It is seen that out of 12 samples (each sample being the average of 4 thin section modal analyses), 10 fall in the field of sub-litharenite and only two fall under sub-arkose.

Table 30 : Modal composition of Talchir Sandstone in the area of study.

Sandstone Facies	Massive sandstone					Cross-stratified sandstone					Inter-bedded sandstone	
Composition	1	2	3	4	5	1	2	3	4	5	1	2
Quartz	80.40	83.00	77.00	77.33	81.00	75.33	80.33	72.66	78.66	81.33	85.33	84.33
Feldspar	4.40	3.30	15.00	8.00	7.66	7.33	7.33	8.00	11.33	8.00	4.66	5.00
Rock Fragments												
Quartzite/ Quartz Schist	6.00	1.66	1.66	2.00	1.00	2.33	3.00	2.66	3.33	1.33	1.00	0.66
Phyllite/ Slate	1.60	1.00	1.00	1.66	0.66	0.66	-	-	1.31	0.66	0.66	0.66
Micritic Limestone	0.40	-	-	-	0.66	-	1.66	0.66	-	-	-	-
Chert	1.20	0.66	-	0.33	-	-	0.66	0.66	-	-	1.00	1.00
Heavies	5.60	10.26	4.99	10.00	8.32	14.32	6.99	14.00	4.98	6.66	7.32	7.98

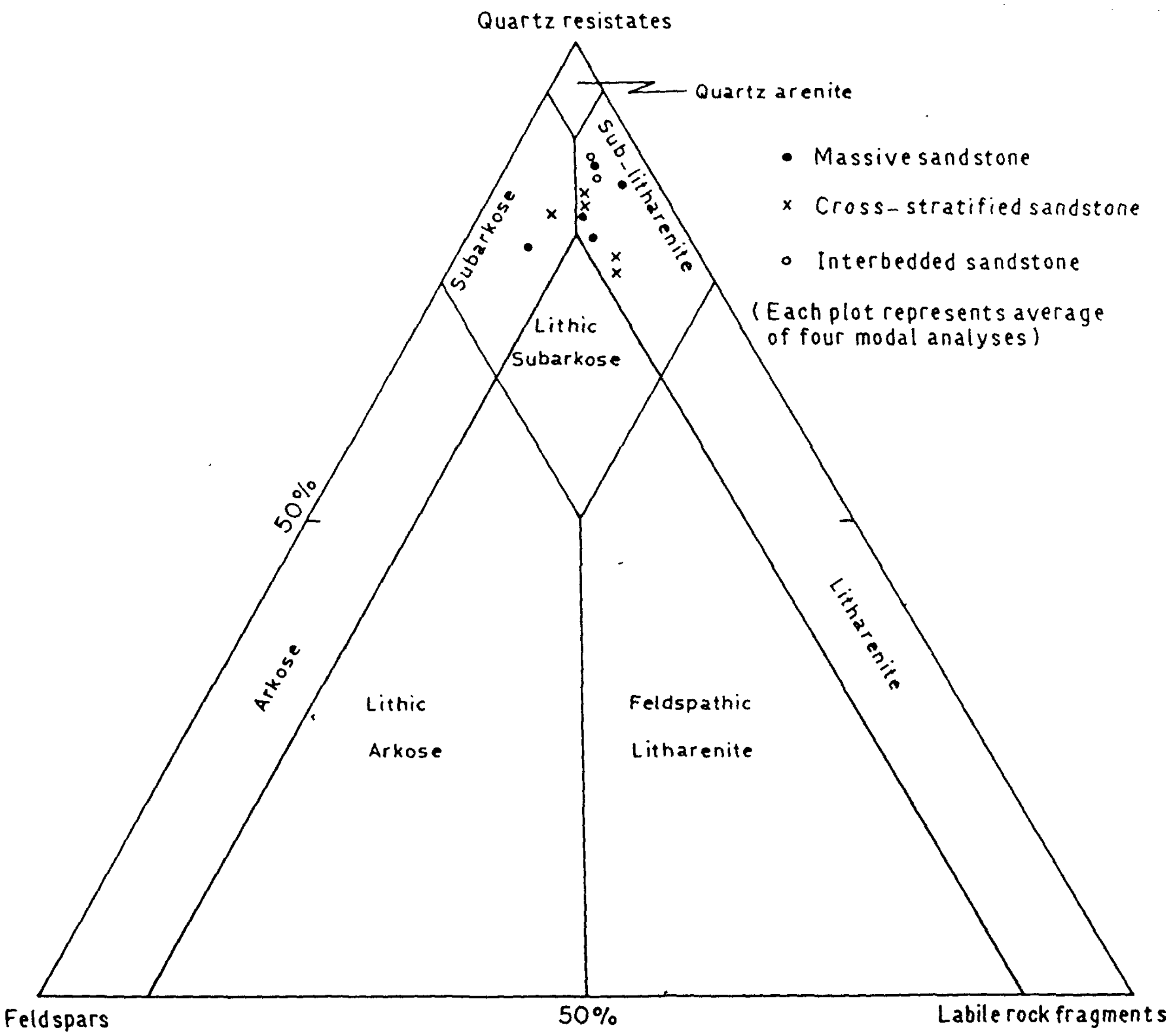

FIG.29. CLASSIFICATION OF TALCHIR SANDSTONES

EXPLANATION OF PLATE XV

Photomicrographs of Sandstones

Figure 1 Framework of the rock is normal. Grains show tangential to slightly straight contacts.

Note a moderate sorting and sub-angular to sub-rounded quartz grains. Grains of feldspars are larger in size and show better rounding.

(x 15)

Figure 2 Large scale replacement of quartz grains by micritic carbonate cement. This has resulted in the development of a disrupted framework.

Note that the grains of quartz appear sharply angular due to corrosion.

(Cross-nicol x 30)

Figure 3 In the lower part of the photographs the sandstone is silica cemented while in the upper part it is cemented sparry calcite. The framework is normal in patches cemented by silica and is disrupted where calcite cement occurs.

(Cross-nicol x 75)

PLATE XV

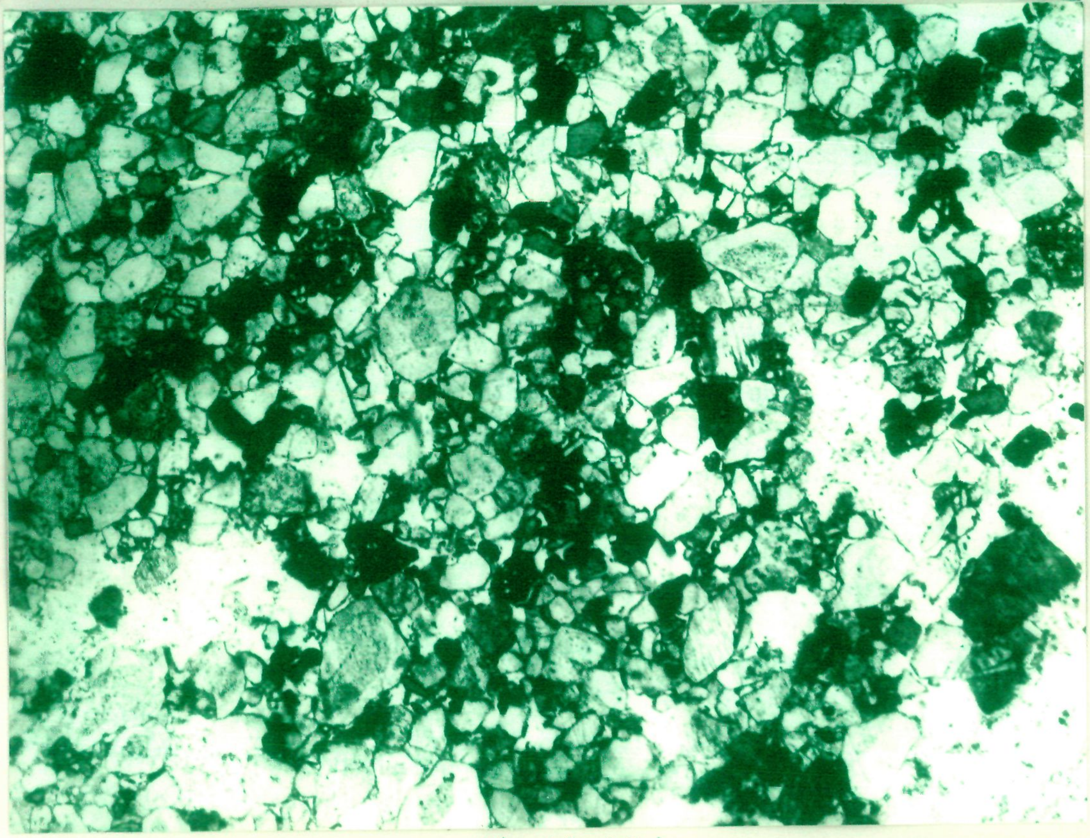

Fig. 1 (x 15)

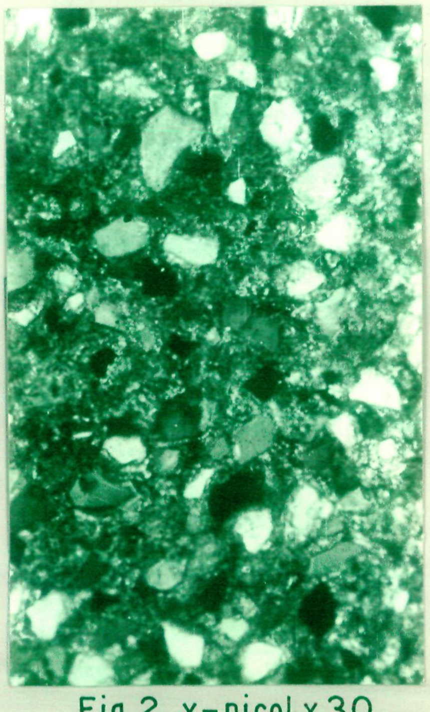

Fig. 2. x-nicol x 30

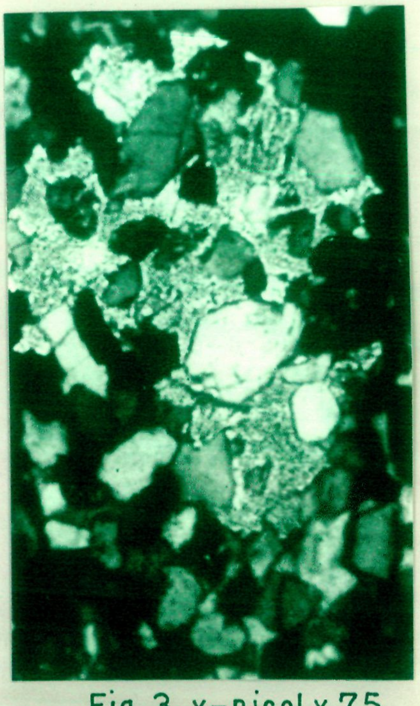

Fig. 3. x-nicol x 75

The framework of the sandstones is normal in most cases, the contacts between grains being tangential or slightly straight (Plate-15, Fig. 1). However, in some thin sections it is observed that the framework is disrupted (Plate-15, Fig. 2). The disruption in all such cases is not due to abundance of matrix but has been caused by large scale replacement of framework constituents (mostly quartz) by calcareous cement. In some instances the replacement of detrital grains of quartz is so extensive that entire grains have been replaced leaving behind only tiny vestiges. Evidence to prove the secondary disruption of an originally normal framework is provided by those sandstones in which calcite and silica cements occur together but in separate patches. It is observed that whereas the framework is normal in areas cemented by silica,it is disrupted in areas cemented by calcite (Plate-15, Fig. 3). This feature clearly indicates that the original framework of the rock was normal at the time of sedimentation and the apparent disruption now seen is due to widespread replacement of quartz grains by the carbonate cement.

Quartz : Quartz occurs as the most dominant mineral in all the three facies constituting 77% to 83% in massive sandstones, 72% to 81% in cross-stratified sandstones and 84% to 85% in the inter-bedded siltstone/sandstone by volume (Plate-15, Fig. 1

and Plate-16, Fig. 1). Majority of the quartz grains show straight to moderate wavy extinction. Most grains are sub-angular to sub-rounded but angular and rounded grains are not uncommon (Plate-16, Fig. 2). The arithmetic mean roundness of quartz grains varies from 0.33 to 0.40 in massive sandstones, 0.33 to 0.38 in cross-stratified sandstones and 0.34 to 0.37 in inter-bedded siltstone/sandstones. However, a few grains showing overgrowth are well-rounded and may have been derived from older sediments (Plate-16, Fig. 3).

Feldspar : In order of abundance feldspar occurs next to quartz and constitute 3.33% to 15%, 7.33% to 11.33% and 4.66% to 5% by volume in massive, cross-stratified and inter-bedded siltstone/sandstones respectively. Generally, feldspars comprise of microcline, plagioclases, orthoclase and perthite. Most plagioclases and alkali feldspars are fresh to slightly altered (Plate-15, Fig. 1). By and large the potash feldspar grains are more altered (Plate-17, Fig. 1) than the plagioclase. The feldspar grains appear to be sub-rounded to rounded and the arithmetic mean roundness varies from 0.33 to 0.40 in massive sandstone, 0.28 to 0.41 in cross-stratified sandstone and 0.34 to 0.41 in the inter-bedded siltstone/sandstones.

EXPLANATION OF PLATE XVI

Photomicrographs of sandstones

Figure 1 A general view of sandstone as seen in low magnification. Abundance of sub-angular to sub-rounded quartz grains is noteworthy. Grains of feldspar are altered.

(x 15)

Figure 2 Quartz grain showing straight to slightly undulose extinction.

Note the high degree of variation in the roundness of grains.

(Cross-nicol x 75)

Figure 3 Grain of quartz in the centre of the photograph shows abraided overgrowth. The detrital grain is rounded.

(Cross-nicol x 75).

Figure 4 Grains of soft rock fragments are rounded to sub-rounded. They occur as distinct grains not effected by crushing.

(Cross-nicol x 75)

PLATE XVI

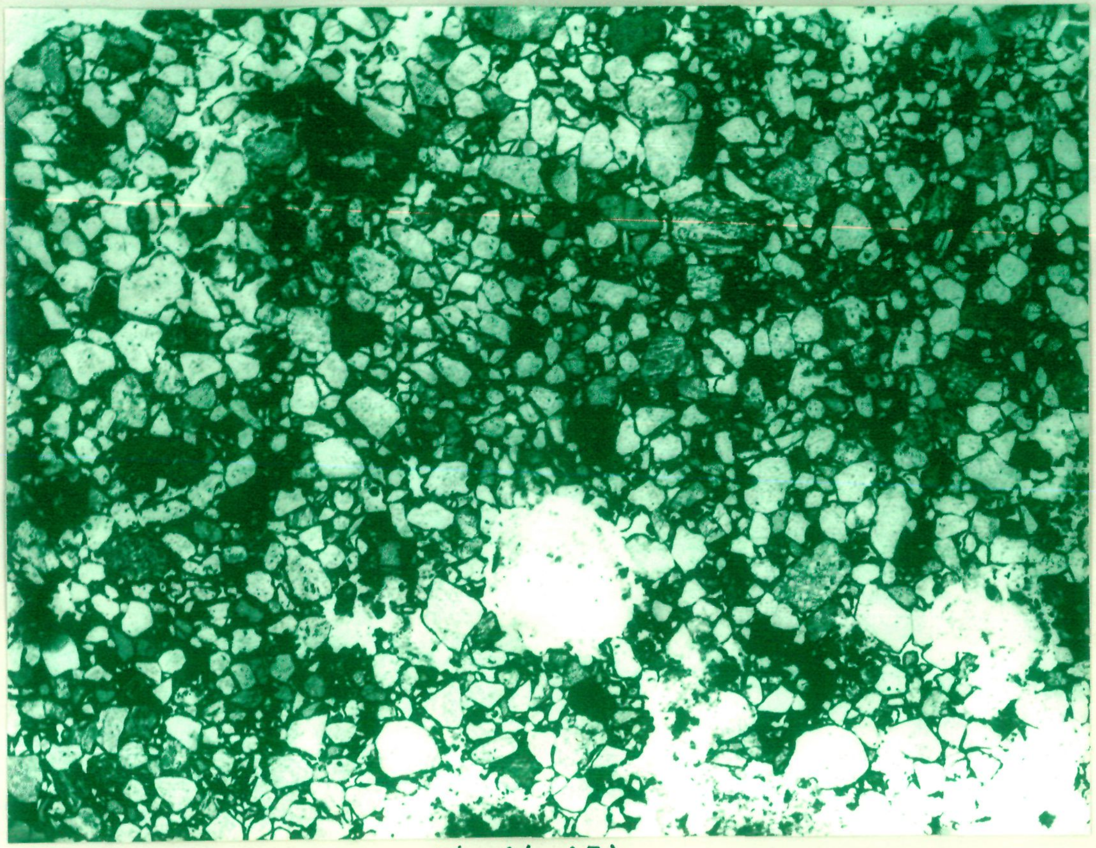

Fig.1(x15)

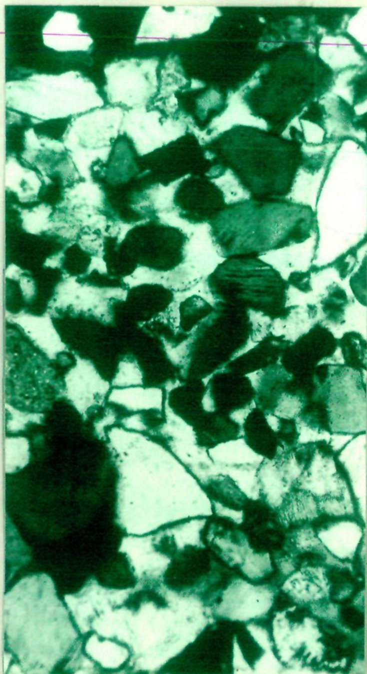

Fig.2. x-nicol x 75

Fig.3. x-nicol x 75

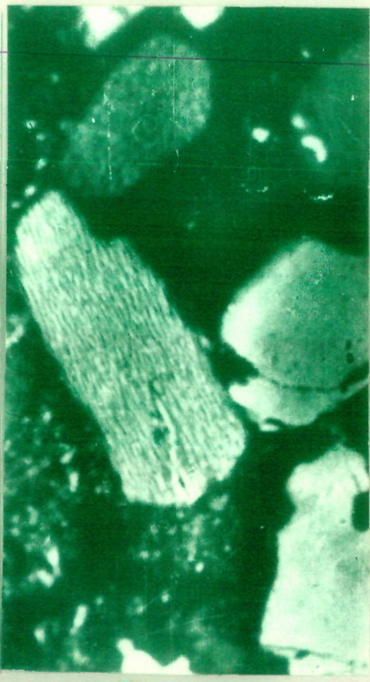

Fig.4. x-nicol x 75

EXPLANATION OF PLATE XVII

Photomicrographs of sandstones

Figure 1 Large sub-rounded grains of feldspars in an altered condition. Quartz grains are sub-angular to sub-rounded and of smaller size.

(Ordinary light x 30)

Figure 2 Fragments of quartzite are larger in size than the quartz grains but show almost the same degree of roundness.

Note moderate sorting and normal framework.

(Cross-nicol x 30)

Figure 30 Soft rock fragments crushed and squeezed between harder quartz grain. The apparent disrupted framework in the central part of the photograph is due to crushing of the soft rock fragment.

(Ordinary light x 75)

Figure 4 Concentration of heavy minerals (mostly garnets) parallel to bedding in cross-stratified sandstones.

(Ordinary light x 75)

PLATE XVII

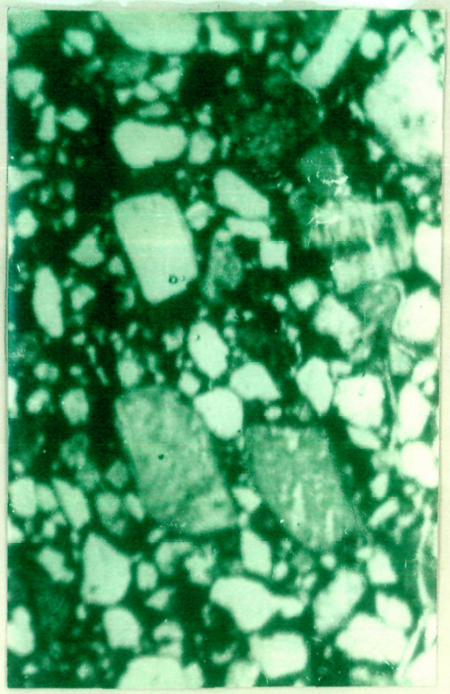
Fig.1. Ordinary light x 30

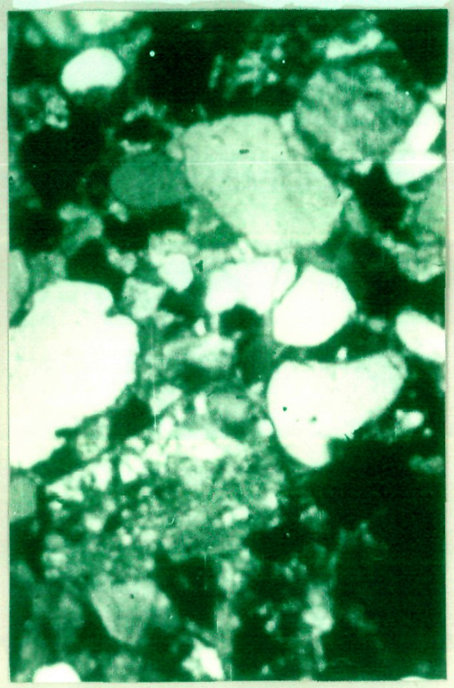
Fig. 2. x-nicol x 30

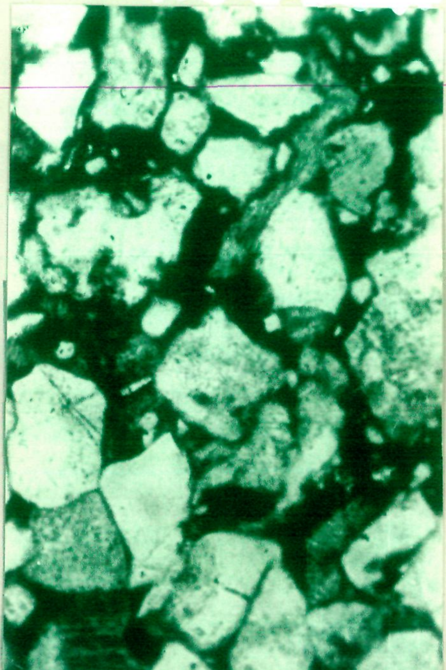
Fig. 3. Ordinary light x 75

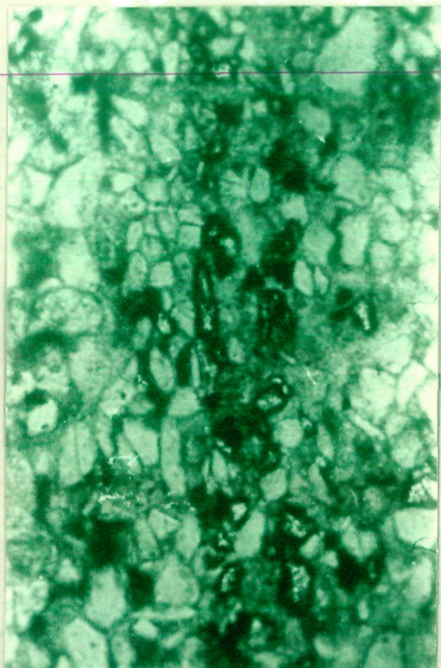
Fig. 4. Ordinary light x 75

<u>Rock Fragments</u> : Rock fragments altogether constitute 2.32% to 9.20% in massive sandstone, 2% to a little more than 4% in cross-stratified sandstone and 2.32% to 2.66% by volume in the inter-bedded siltstone/sandstone. The rock fragments comprise of quartzite/quartz-schist; phyllite/slate, granite/ granite gneiss, micritic limestone and chert. Micritic limestone is not found in the inter-bedded shale and siltstone/ sandstone facies.

Quartzite fragments are generally sub-angular to sub-rounded and are comparatively bigger in size than the other rock fragments (Plate-17, Fig. 2). The constituent quartz grains of quartzite fragments exhibit strongly to slightly undulose extinction and are of the same size as the smaller quartz grains present in the rock.

The soft rock fragments such as phyllite/slate etc. are generally sub-rounded to rounded and they occur both as distinct grains (Plate-16, Fig. 4) and in crushed condition (Plate-17, Fig. 3). In some samples these fragments after crushing produce secondary matrix not distinguishable from the primary matrix.

Granite and granite gneiss is recorded in only one sample of the massive sandstone facies in very small amount(0.4%).

. Micritic limestone and chert are the only sedimentary rock fragments present. Micritic limestone fragments are generally bigger in size than the chert grains but both are sub-rounded to rounded.

3.5.4. Heavy Minerals

19 representative samples, 7 of massive sandstone, 7 of cross-stratified sandstone and 5 of inter-bedded siltstone/ sandstone facies were selected for heavy mineral studies and 300 grains in each slide were counted.

In some specimens of cross-stratified sandstones, heavy minerals (mostly garnets), occur highly concentrated in layers parallel to bedding (Plate-17, Fig. 4).

The data on heavy minerals is presented in Table 31. It is seen that qualitatively and quantitatively the heavy mineral assemblages extracted from the three sandstone facies are not only remarkably similar within themselves but also show equally remarkable likeliness to those obtained from the fine fractions of the lower and upper diamictite units (Tables 15 & 25). Thus heavy mineral assemblages from all investigated lithounits of Talchir Formation are similar.

Table 31 : Heavy Minerals of Talchir Sandstone (per cent by number)

Heavy Minerals	Massive Sandstone		Cross-stratified sandstone		Inter-bedded siltstone/sandstone	
	Range	Average	Range	Average	Range	Average
Garnet (colour-less)	75.33-89.57	82.95	72.34-91.32	83.36	77.92-89.45	82.74
Garnet (pink)	3.90-13.01	7.18	2.02-14.39	7.07	4.54-9.19	7.26
Epidote	1.54-3.64	2.31	1.18-4.16	2.53	1.09-2.06	1.48
Tourma-line	0.34-1.33	0.81	0.28-1.72	0.72	0.72-1.73	1.20
Zircon	0.34-2.00	0.98	0.52-3.13	1.17	0.43-1.09	0.80
Micas	0.30-1.28	0.36	0.28-0.85	0.20	-	-
Opaques	0.68-3.33	1.73	1.04-2.30	1.70	1.81-3.76	2.91
Titanite	1.62-6.17	3.28	0.65-6.43	2.89	0.72-5.62	3.39
Apatite	0.34-1.60	0.51	-	-	-	-
Rutile	-	-	0.28-0.65	0.21	0.36-0.41	0.15

CHAPTER - 4

PALEOCURRENT ANALYSIS

4.1. INTRODUCTION

A southerly and south-easterly paleoslope, and consequently sediment transport direction, in the Son-Mahanadi Gondwana belt was visualised by early workers on the basis of clasts occurring in the Talchir and younger formations which could be matched with similar lithologies in the older Bijawar and Vindhyan rocks occurring further north and north-west of this Gondwana basin (Ball, 1873, p. 28; Fermor, 1914, p. 167; Gee, 1932, p. 37; Fox, 1934; Pascoe, 1959).

Paleocurrent studies on modern lines on the Gondwana rocks of Son-Mahanadi valley have proved beyond doubt that the earlier concept based on lithological similarities was not correct and that in this region the paleo-drainage was northerly and north-westerly (Ghosh and Bandopadhyay, 1967; Casshyap and Jain, 1970; Choudhury and Basu, 1971; Choudhury, 1971; Ghosh and Mitra, 1972; Casshyap, 1973; Mitra et al., 1975; Casshyap, 1982). It may, however, be noted that in the investigations mentioned above the emphasis was on Barakar and younger formations as they abound in cross-stratification. Detailed paleocurrent studies restricted to the Talchir Formation in this belt have so far not been made and this investigation is first of its kind though restricted to a small area in the central part of the western margin of the Son-Mahanadi Gondwana belt.

The sediment dispersal pattern of the Talchir sediments in the study area has been investigated primarily with the help of two vector properties, namely, the long axis orientation of the clasts in the diamictite units and cross-stratification (including cross-laminations) in sandstones and siltstones. In addition to these, the trend of channel axes in sandstone facies were measured whenever and wherever these could be seen but the number of such readings is small. Parameters such as orientation of ripple crests and other directional sedimentary structures have not been used because they occur rarely in rocks of the study area and are, therefore, hardly useful in paleocurrent reconstruction.

At two localities in the Tan Nadi, 400 meters and 700 meters upstream and downstream respectively from the road bridge, striated pavements with crescentic marks are seen in the basement rocks indicating the direction of ice movement in the valley. These pavements have been helpful in reconstructing the paleocurrent patterns in the area and in understanding the mode of the deposition of the Talchir rocks.

Two paleocurrent maps, one based on clast fabric and the other on cross-stratification foreset dip azimuths and channel axes, have been prepared and are presented as Figures 30 and 32

Almost all accessible outcrops of diamictites were studied for the orientation of long axes of clasts. However, it may be stated that owing to deep weathering of rocks, outcrops are generally poorly preserved and in some cases do not permit accurate measurements. Further, diamictites in the area do not form continuous outcrops. They occur as relatively small isolated outcrops inter-tongued with sandstones, siltstones and shales.

Cross-stratification in the true sense is rather rare in the Talchir sandstones. Profuse development of this structure is seen only in sections exposed along the Kharpari nala in the northern part of the area. Some outcrops showing small scale cross-stratification are seen in sandstones in the northern part of the area along the small isolated scarps on the southern bank of Hasdo River in the neighbourhood of Korbi village. Isolated single sets of ripple cross-laminations, though rare, are sometimes seen in sandstones and siltstones.

Within the above limitations of the availability of data, an attempt has been made to work out the sediment dispersal pattern of the Talchir sediments in the study area and to interpret the paleocurrent data in terms of paleogeomorphology, paleoslope and, to some extent, the depositional environments of the various facies constituting the Talchir sediments.

4.2. CLAST FABRIC ANALYSIS

The term fabric is used to designate the spatial orientation of constituents comprising the rock. The fabric is said to be 'Isotropic' when the fabric elements are randomly oriented while it is described as 'anisotropic' when the fabric elements show orientation predominently in one direction. When clastic sedimentary rocks are deposited in response to a moving force (glacial movement, wind movement or movement of water) they are likely to acquire a preferred orientation of their fabric elements (long axes of pebble, long axes of sand grains, characteristic orientation of shell fragments, wood fragments, etc.). The anisotropic fabric thus developed is called 'apposition' fabric or sedimentary fabric in contrast to deformation fabric or growth fabric.

4.2.1. Methods of Study

The Talchir diamictites occur generally in stream and river beds forming flat grounds, or gentle slopes. Vertical faces of diamictite outcrops are relatively few and apart. In the majority of outcrops the clasts occur sparsely distributed. The method used in the present study for the measurement of long axis orientation of clasts differs considerably from that of other workers. Since, as mentioned above, exposures of diamictite do not commonly occur in vertical faces, the methodology adopted by Wadell (1936), Karlstrom (1952) and Schlee (1957), could not be used. Moreover, due to reasons of logistics it was impossible to carry clasts in large numbers to the laboratory. All measurements, therefore, had to be completed in the field. To overcome the effects of shape and size of clasts on orientation (Cailleux, 1945; White, 1952; Brinkman, 1955; Harrison, 1957; Schlee, 1957; etc.), only the significantly elongated clasts measuring between 1 cm to 40 cms and showing an elongation ratio of 2.5 or more were selected for measurement.

The procedure adopted for measurements of the long axes orientation of clasts was simple. Each selected clast was carefully taken out of the matrix, great care being taken not to disturb the matrix below the clast. In most cases this operation was not difficult but where the enclosing matrix was hard, the clasts were carefully chiselled out. The clasts so removed invariably left their impression in the enclosing matrix. After removing the clast and marking on it the points of emergence of the long axis with a piece of chalk, the clasts were fitted back into their original position. A pencil was then held parallel to the line joining the two chalk marks and its orientation was measured with a Brunton compass.

The number of measurements at various outcrops of the diamictite varied from a minimum of 50 to a maximum of 115 depending upon the availability of suitable clasts. Due to paucity of clasts of suitable shape and size in particular and the sparseness of clasts in outcrops in general, it was not possible to collect more data. Studies of Holmes (1941, p. 1308), however, indicate that measurement of even 50 clasts is enough to yield significant results. A total of 1545 measurements of orientation of long axes of clasts were made from 23 exposures, 11 from basal diamictite and 12 from upper diamictite.

4.2.2. Statistical Treatment of Orientation Data

The azimuth of long axes of clasts was tabulated for each outcrop separately into 30° classes. The data so obtained were presented as rose diagrams (2θ distribution) (Fig. 30).

Since it is not always possible to determine whether or not preferred orientation is present in a given population of fabric elements by a mere visual inspection of rose diagrams, a more rigorous method is required to establish the presence or absence of anisotropism. Further, the significance of this orientation data is best understood if it is summarized statistically.

The average direction of preferred orientation was determined by the vector summation method. Since the data

82°,15′
22°
55′
25′
35′
82,45′
22°
55′
45
45′
F
F
1K
1610
KORBI
3K
2K
PUTA
2831
3B
1R
1832
1H
2H
2R
3R
2173
T A N N A D I
1B
JATGA
2M
3M
LATGARH NALA
MARHAI
1M
3H
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4T
2190
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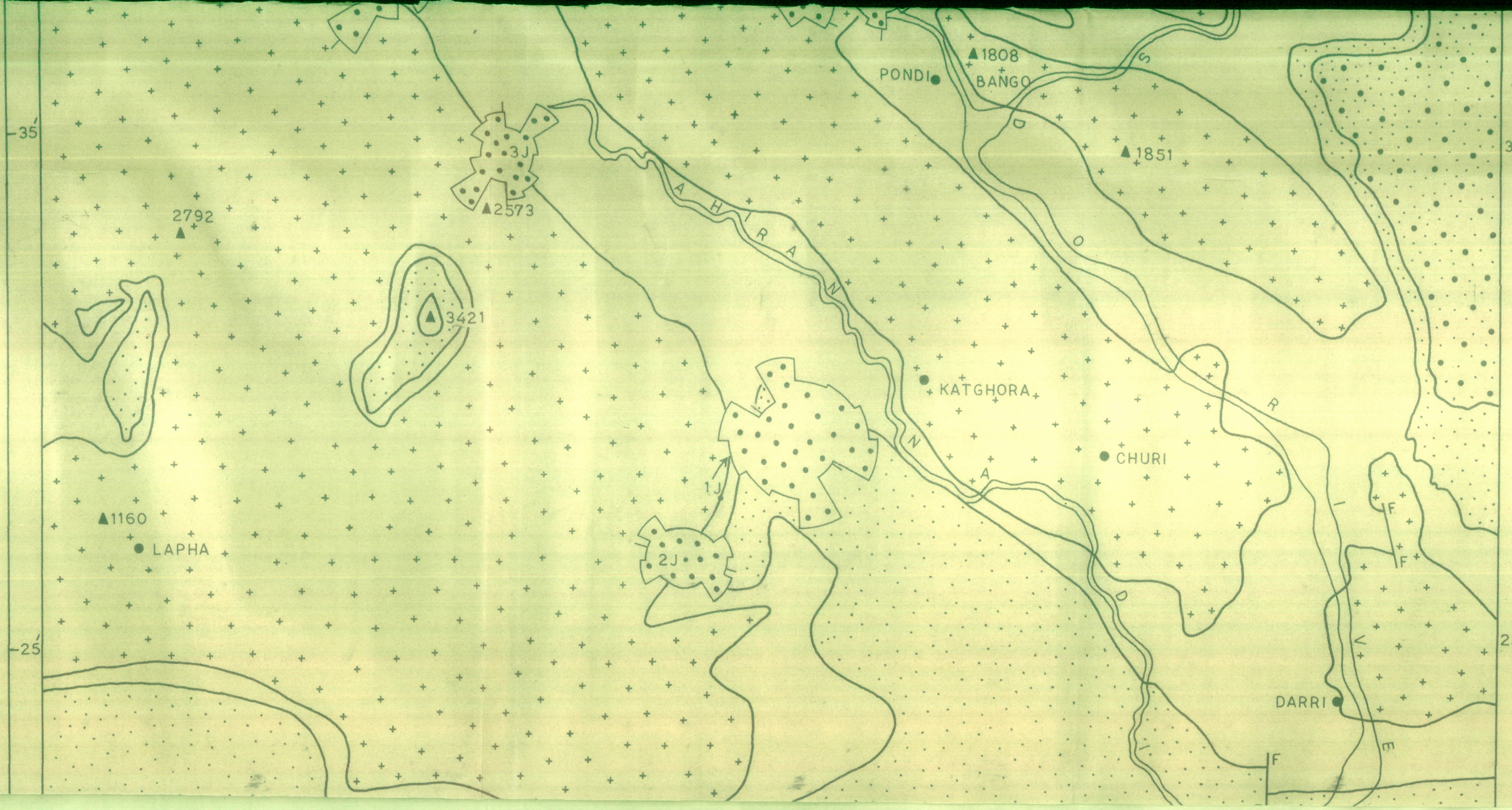
2B
1T
3T
H A


35′
25′
PONDI
1808
BANGO
1851
3J
2573
2792
3421
AHIRAN NADI
DORI NADI
KATGHORA
CHURI
1J
2J
1160
LAPHA
DARRI
F

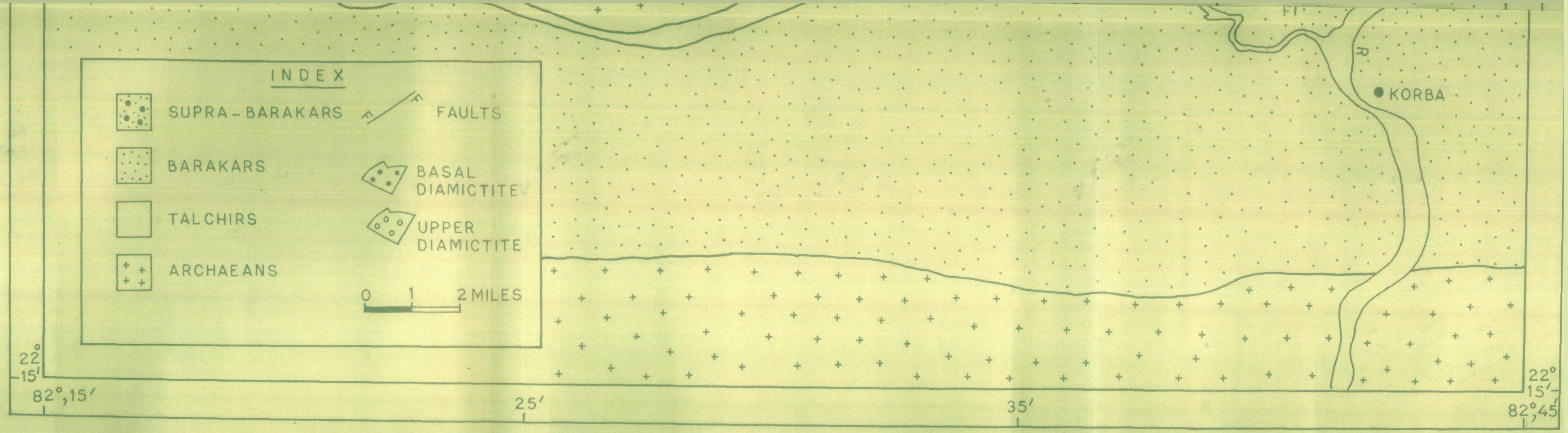


FIG.30. PALEOCURRENT MAP OF THE AREA BASED ON CLAST FABRIC

at hand are circularly dispersed and as the choice of the origin strongly influences the value of the mean (Jizba, 1953; Chayes, 1954; Curray, 1956; Pincus, 1956), the method of moment analysis was discarded in favour of the vector summation method (2θ distribution) as applied to circularly dispersed frequency distributions (Reiche, 1938; Curray, 1956; Pincus, 1956).

The vector summation method consists of trignometrically computing the north-south and east-west components of each group of unit vectors (Curray, 1956) as follows :

N-S component = $n \text{ Cos } 2\theta$

E-W component = $n \text{ Sin } 2\theta$

where n is the number of unit vectors in a group and $\emptyset$ is the mid-point of the azimuthal group. The azimuth of the resultant vector $\theta V = 1/2 \text{ arc tan } \frac{\leq n \text{ Sin } 2\theta}{\leq n \text{ Cos } 2\theta}$. The resultant vector azimuth is a measure of the average direction of preferred orientation and has the same significance as the mean calculated by moment analysis.

The vector magnitude (in per cent) and variance (S^2) were computed for grouped data for 0-180^o distribution. The Rayleigh Test as described by Curray, (1956, p. 125) was applied to test the significance of preferred orientation and the hypothesis that the distribution was significantly different from a random population was tested at 5 per cent level.

The above method of statistical analysis is, strictly speaking, applicable to normal frequency distributions only.

However, a review of the rose diagrams representing the long axes orientation of clasts of the basal and upper diamictites in the study area (Fig. 29) shows that the distribution of the long axes of clasts of the basal diamictite is bimodal in eight (8) out of eleven (11) localities while the same is true at two (2) localities only in the upper diamictite.

Bimodality of distribution of the long axes of clasts appears most likely to be due to the mixing of two distinct populations, each showing a direction of preferred orientation of its own although this feature is known to arise from other causes also. In such cases it has been found more meaningful to separate the two populations and calculate the orientation statistics separately for each sub-population. This has been done by splitting the entire population into two sub-populations, the dividing line between the two passing through the mid-point of the smallest class between the two modes. The vector mean for each sub-population (ΘV_1 and ΘV_2) was calculated separately to find out the two directions of preferred orientation as also to ascertain the angle between the two orientation directions.

Table 32 lists the orientation statistics of long axes of clasts of the basal diamictite. It is noteworthy that at all localities where the long axes show bimodal distribution, the angle between the vector mean directions of the sub-populations ($\Theta V_1 \wedge \Theta V_2$) is very nearly 90 degrees indicating that clasts are preferentially oriented in directions nearly at right angles.

Table 32 : Orientation statistics of long axes of clast of Basal Diamictite

S. No.	Out-crop No.	Nature of Fabric	Vector Mean Direction				L%			Statistical significance (Rayleigh Test)
			Unimodal Distribution	Bimodal Distribution			Unimodal Distribution	Bimodal Distribution		
				Primary Population	Secondary Population	Difference		Primary population	Secondary population	
			θV	θV_1	θV_2	$\theta V_1 \wedge \theta V_2$	L%	$L_1\%$	$L_2\%$	
1.	1J	Bimodal	-	$177^{o}-357^{o}$	$91^{o}-271^{o}$	86^{o}	-	63%	64%	Significant
2.	2J	Bimodal	-	$140^{o}-320^{o}$	$70^{o}-250^{o}$	70^{o}	-	68%	64%	Significant
3.	3J	Bimodal	-	$60^{o}-240^{o}$	$144^{o}-324^{o}$	84^{o}	-	59%	58%	Significant
4.	1T	Unimodal	$105^{o}-285^{o}$	-	-	-	54%	-	-	Significant
5.	2T	Bimodal	-	$2^{o}-182^{o}$	$92^{o}-272^{o}$	90^{o}	-	64%	64%	Significant
6.	3T	Bimodal	-	$22^{o}-202^{o}$	$129^{o}-309^{o}$	73^{o}	-	72%	69%	Significant
7.	4T	Unimodal	$171^{o}-351^{o}$	-	-	-	25%	-	-	Significant
8.	2B	Bimodal	-	$45^{o}-225^{o}$	$135^{o}-315^{o}$	90^{o}	-	48%	48%	Significant
9.	1R	Bimodal	-	$40^{o}-220^{o}$	$130^{o}-310^{o}$	90^{o}	-	52%	48%	Significant
10.	2R	Bimodal	-	$43^{o}-223^{o}$	$138^{o}-318^{o}$	85^{o}	-	74%	72%	Significant
11.	3R	Unimodal	$176^{o}-356^{o}$	-	-	-	65%	-	-	Significant

Each sub-population when tested statistically (Rayleigh Test), shows that there are more than 95 per cent chances that the long axes of clasts show a distinct preferred orientation.

Table 33 presents the orientation statistics of long axes of clasts of the Upper Diamictite units. As mentioned earlier only two samples show a bimodal frequency distribution of the long axes while ten are unimodal. Only at one outcrop (No. 2H), the sample shows that anisotropism is not present at 5 per cent level.

It is interesting to compare the orientation characteristics of long axes of clasts in the Basal and Upper Diamictite horizons. Table 34 summarises the salient differences between the fabric features of the two horizons of the Talchir diamictites in the study area. The Basal Diamictite basically shows bimodal distribution, the two modes being nearly at right angles while the Upper Diamictite is fundamentally unimodal. The outcrop to outcrop variation in vector mean direction of primary modes is slightly greater in the Basal Diamictite as compared to the Upper Diamictite. Finally, there is a much greater scatter of variance values in the Basal Diamictite as compared to the Upper Diamictite. The possible significance of these differences in relation to depositional processes is discussed elsewhere.

Table 33 : Orientation statistics of long axes of clasts of Upper Diamictite.

S. No.	Out-crop No.	Nature of Fabric	Vector Mean Direction: Unimodal Distribution θV	Vector Mean Direction: Bimodal Distribution: Primary Population θV_1	Bimodal Distribution: Secondary Population θV_2	Bimodal Distribution: Difference $\theta V_1 \wedge \theta V_2$	L%: Unimodal Distribution L%	L%: Bimodal Distribution: Primary Population $L_1\%$	Bimodal Distribution: Secondary Population $L_2\%$	Statistical Significance at 0.5 level (Rayleigh Test)
1.	1M	Bimodal	-	$44^{\circ}-224^{\circ}$	$125^{\circ}-305^{\circ}$	81°	-	77%	59%	Significant
2.	2M	Unimodal	$68^{\circ}-248^{\circ}$	-	-	-	37%	-	-	Significant
3.	3M	Unimodal	$87^{\circ}-267^{\circ}$	-	-	-	49%	-	-	Significant
4.	1H	Unimodal	$8^{\circ}-188^{\circ}$	-	-	-	23%	-	-	Significant
5.	2H	Unimodal	$126^{\circ}-306^{\circ}$	-	-	-	14%	-	-	Not Significant
6.	3H	Unimodal	$166^{\circ}-346^{\circ}$	-	-	-	30%	-	-	Significant
7.	2K	Unimodal	$66^{\circ}-246^{\circ}$	-	-	-	23%	-	-	Significant
8.	3K	Bimodal	-	$153^{\circ}-333^{\circ}$	$33^{\circ}-213^{\circ}$	60°	-	66%	59%	Significant
9.	1	Unimodal	$142^{\circ}-322^{\circ}$	-	-	-	35%	-	-	Significant
10.	1K	Unimodal	$61^{\circ}-241^{\circ}$	-	-	-	23%	-	-	Significant
11.	1B	Unimodal	$49^{\circ}-229^{9}$	-	-	-	29%	-	-	Significant
12.	3B	Unimodal	$65^{\circ}-245^{\circ}$	-	-	-	37%	-	-	Significant

Table 34 : Differences between the fabric features of the two Talchir Diamictite units in the study area.

Distinguishing Features	Basal Diamictite	Upper Diamictite
1. Nature of frequency distribution of long axes orientation	Bimodal in 8 out of 11 outcrops (72%)	Bimodal in 2 out of 12 outcrops (16.6%)
2. Outcrop to outcrop variation in ΘV of primary modes	89° of arc	79° of arc
3. Variance (S^2) values		
Below 2000	At 1 outcrop	None
2000-3000	At 5 outcrops	At 10 outcrops
3000-4000	At 4 outcrops	At 2 outcrops
Above 4000	At 1 outcrop	None

4.3. CROSS-STRATIFICATION FORESET DIP AZIMUTH

4.3.1. Sampling and Measurement

The sampling pattern adopted for cross-stratification dip azimuth study was not based on any conventional or predetermined system because the outcrops of the various rock units occur irregularly due to alluvium cover and also because no study of a similar kind was ever made in this area which could provide guide lines for spacing the observation points.

Cross-stratification measurements were taken from all accessible outcrops. However, this structure is not very abundant in the rocks of the Talchir Formation and is observed only in some sandstone beds. In all 307 cross-stratification dip azimuths spread over 13 localities, were measured from the study area.

The method of measurement of cross-stratification dip azimuths varied from outcrop to outcrop depending upon the nature of exposures. In outcrops where the foreset planes were exposed (as in Kharpari <u>nala</u> Section), the dip azimuths were measured directly with the brunton compass. In sandstones where such planes could not be measured directly the azimuth and dip amounts of individual foreset planes were measured in two non-parallel sections and the azimuth and amount of the true dip was determined using an equal area Schmidt net. Since strata in the area are either horizontally disposed or show very low dips (3^{o}-7^{o}), no tilt correction was considered necessary.

4.3.2. Foreset Dip Azimuth Statistics

The dip azimuth of cross-stratification foreset planes were plotted as rose diagrams with 30° interval (Fig. 31). The vector mean azimuth ($\bar{\theta}V$), vector magnitude (L%) and variance (S^2) at each locality were calculated (Table 35). The vector mean azimuth directions have also been plotted on a map of the area (Fig. 31) to illustrate the sediment dispersal pattern during the deposition of the rocks under consideration.

A review of Figure 30 showing the rose diagrams of cross-stratification foreset dip azimuths shows that out of 13 diagrams 6 are unimodal and fan shaped while 7 are bimodal in which the two modes are situated mostly at an angle of 60° to 90° (only in one case the angle is 120°. It is interesting to note that the foreset dip azimuths of cross-strata show a unimodal fan-shaped distribution in the northern most part of the area which is far removed from the basement Archean rocks while the distribution is bimodal in outcrops closer to Archaean rocks. It is very likely that the basement topography at the time of deposition of the Talchir rocks played an important role in producing variability of the current system in response to which the sandstones were deposited.

Table 35 : Cross-stratification foreset dip azimuth.

Outcrop No.	n	ΘV	L%	s^2	S	Uni/ Bimodal	Locality
1	21	31°	78	1765	42	Bimodal	Korba
2	34	80°	76	1898	43	"	Jhulna Nala
3	24	342°	88	807	28	"	Pondi-Bango
4	8	355°	50	1957	44	"	Road Section
5	22	45°	58	3942	63	"	Road Section contact of T/B*
6	62	13°	61	1315	36	"	Kharpari Nala downstream
7	62	13°	61	1315	36	"	Kharpari Nala downstream
8	16	330°	95	360	19	Unimodal	Kharpari Nala junction of Hasdo River
9	8	41°	95	370	19	"	Phulsar Nala
10	11	282°	72	2926	54	"	Hasdo River Korbi-downstream
11	20	294°	92	578	24	"	Hasdo River - Korbi 400 m upstream
12	11	280°	98	147	12	"	Hasdo River - Korbi Ist turn
13	8	280°	85	1228	35	"	Bakai Nadi

* T = Talchir Formation, B = Barakar Formation

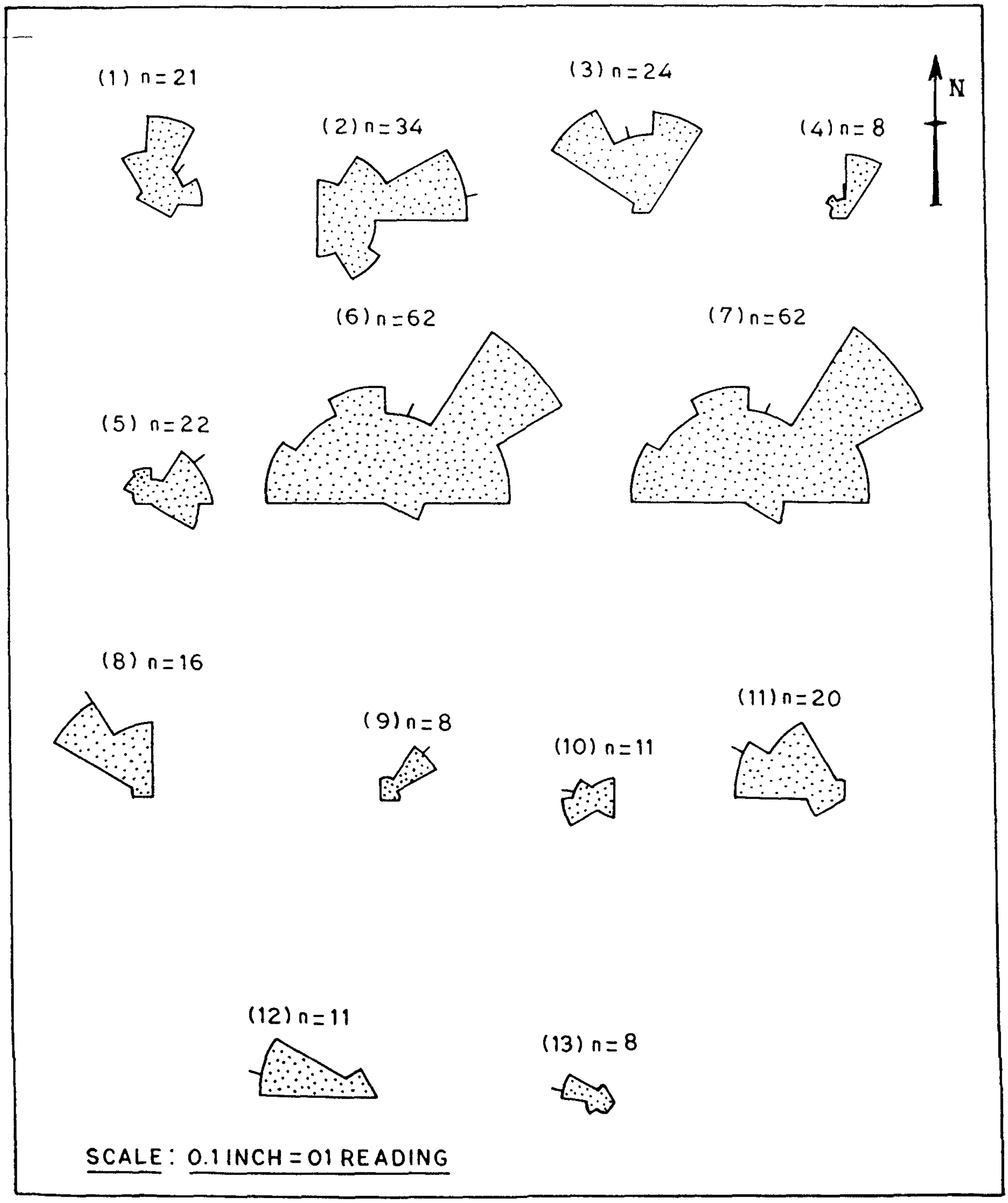


FIG.31. CIRCULAR ROSE DIAGRAMS SHOWING DISTRIBUTION OF CROSS-STRATIFICATION FORESET DIP AZIMUTH IN TALCHIR SANDSTONES

4.4. CHANNEL AXES

As mentioned earlier, some sandstones and siltstones in the study area show channels within them. The azimuth of the axes of these channels were measured at 12 localities (Table 36) and are shown in paleocurrent map in Figure 32. The trend of the channel axes show a close correlation with the orientation of foreset dip azimuths of cross-strata.

4.5. STRIATIONS AND CRESCENTIC MARKS ON BASEMENT ROCKS

At two localities in the Tan Nadi, one 400 meters upstream and other 700 meters downstream of the road bridge, the Archaean basement rocks show striations and crescentic marks considered by Ahmad *et al.*(1976) and Casshyap and Srivastava (1986) as having been produced by glacial action. The directions given by these marks (304° and 298°) are in conformity with the one obtained from clast fabric orientation studies (285°) in Basal Diamictite at a nearby locality and orientation of channel axes in sandstones (286°) in outcrops occurring at a distance of about 350 meters north of the outcrop of striated pavement.

4.6. SYNTHESIS OF PALEOCURRENT STUDIES

The paleocurrent patterns existing during the deposition

Table 36 : Average trend of channel axes in sandstones/ siltstones of the study area.

S.No.	Locality	Number of channels measured	Average Trend
1	Korba	2	32^{o}-212^{o}
2	Jhulna Nala	3	83^{o}-263^{o}
3	Tan Nadi (Gursian)	3	106^{o}-286^{o}
4	Pondi-Bango	3	146^{o}-326^{o}
5	Lathgarh Nala (Marhai)	3	84^{o}-264^{o}
6	Hasdo River (Ambikapur Road)	1	0^{o}-180^{o}
7	Hasdo River-Korbi 400 m Upstream	6	151^{o}-331^{o}
8	Hasdo River-Korbi Up to Second Turn Upstream	3	130^{o}-310^{o}
9	Hasdo River-Korbi Top of Second Turn Upstream	1	115^{o}-295^{o}
10	Hasdo River-Korbi Downstream	2	139^{o}-319^{o}
11	Tan Nadi-Jatga	1	95^{o}-275^{o}
12	Bansajhal Nala Jatga	1	100^{o}-280^{o}

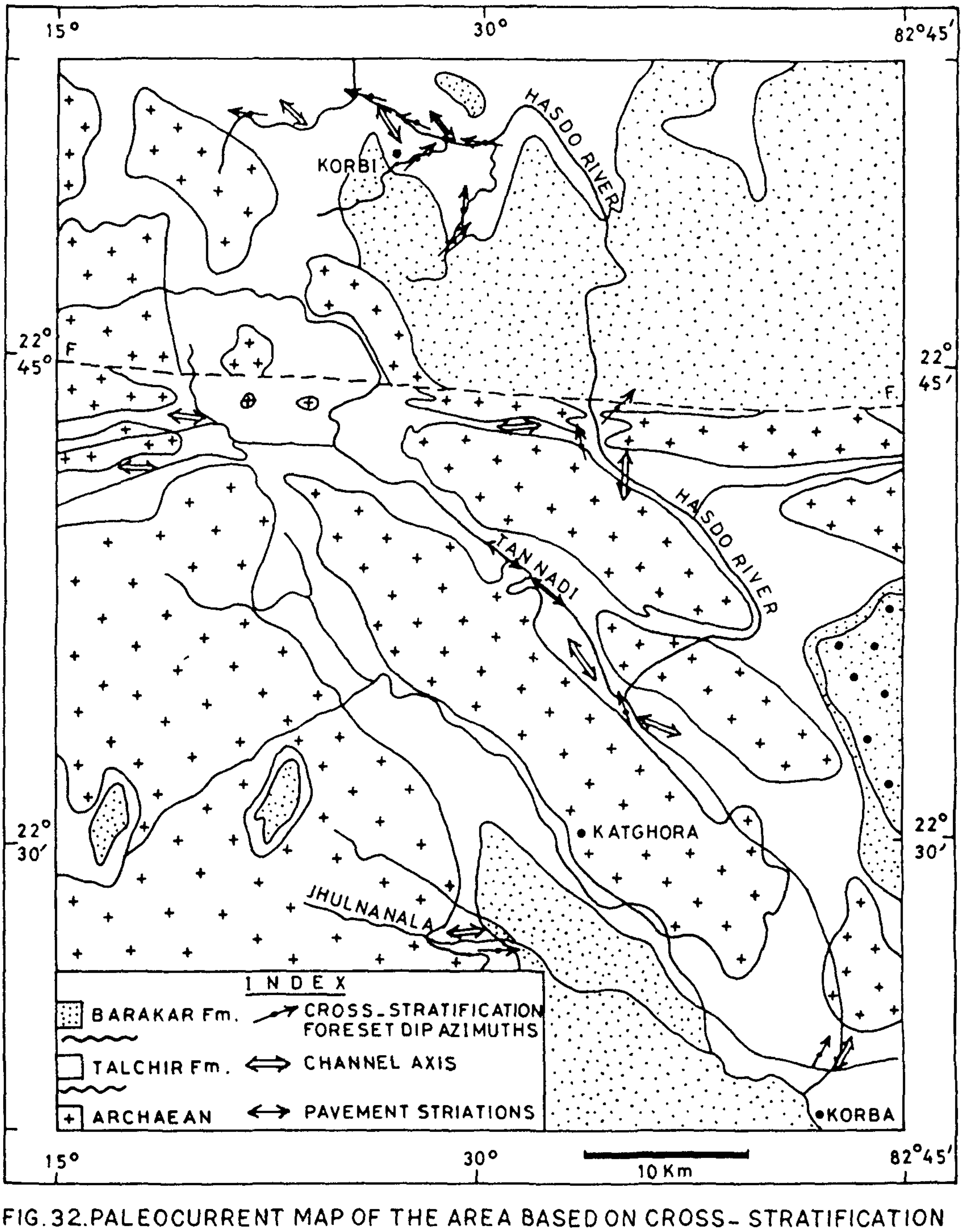


FIG. 32. PALEOCURRENT MAP OF THE AREA BASED ON CROSS-STRATIFICATION FORESET DIP AZIMUTHS AND CHANNEL AXES IN TALCHIR SANDSTONE/ SILTSTONE.

of the rocks of the Talchir Formation have been reconstructed on the basis of clast fabric of the basal and upper diamictite horizons and on the basis of cross-stratification foreset dip azimuths and trends of channel axes in sandstones. The basal diamictite rests directly on the basement rocks followed by the upper diamictite higher up in the sequence. The cross-stratified sandstones occur nearly at the top of the Talchir Formation. Thus the paleocurrent data obtained from the study area represents the changing patterns of sediment dispersal through time and space.

During the time of deposition of the basal diamictite, the depositing agency moved in a general easterly and north-easterly direction as deciphered from the fabric patterns in Jhulna nala and in outcrops further north-west along the Ahiran river. The direction seems to have slightly changed to a northerly direction in the valley of the Tan Nadi. In outcrops east of the road bridge on the Tan Nadi, the direction obtained from the fabric studies is 285° which compares very favourably with the direction of 304° indicated by the striated pavement on the basement rocks immediately over which the basal diamictite lies. It thus appears that the depositing agency in this area entered the Tan valley in a northerly direction and then continued its course along the valley in a north-westerly direction. Further north-north-east of Marhai and in the vicinity of the road bridge on the Hasdo river, the paleoflow direction is northerly and north-easterly along valleys in between the Archaean ridges.

The paleoflow directions obtained from the fabric study of the upper diamictite is significantly different from that obtained from the basal diamictite inasmuch as the directions are almost invariably parallel to the valleys in which the Talchir outcrops occur. It is most likely that the agency which deposited the upper diamictite was such that its course was determined entirely by the then existing topography.

Almost at the end of Talchir sedimentation, the sediment dispersal pattern obtained from the sandstones is very similar to the pattern existing at the time of deposition of the upper diamictite. The flow direction is almost always parallel to the valleys in which the Talchirs were deposited and is directed in the north-westerly direction.

CHAPTER - 5

PROVENANCE, BASIN EVOLUTION AND SEDIMENTATION HISTORY

5.1. GENERAL REMARKS

The foregoing detailed investigations of the facies characteristics, petrography and sediment dispersal pattern of the Talchir Formation forms the basis for attempting to determine the composition and location of the provenance which supplied sediments to the basin, the geomorphic nature of the basin of deposition and finally the depositional framework and sedimentation history of this formation in the study area.

The regional paleoslope, worked out on the basis of paleocurrent analysis, is a pointer to the direction in which the provenance of the Talchir sediments lay. It has been possible to actually locate the provenance by matching the lithology of the clasts in diamictites with similar lithologies existing today in the area indicated by the paleocurrent patterns, as also with the help of the mineral composition of fine fractions of diamictites and sandstones and the heavy mineral suits present therein.

The study of vertical and lateral distribution of Talchir lithofacies and detailed field work gives insight into the question of geomorphology of the basin floor at the time of commencement of Talchir sedimentation. An attempt has been made to show that basin geomorphology has played an important part in the evolution of the lithic fill in the different parts of the area under study.

An integrated study of the facies distribution, sedimentary and petrographic characters and varying styles of sediment dispersal patterns through space and time has enabled the author to present the history of sedimentation in regard to the study area.

5.2. LOCATION OF PROVENANCE

In order to locate the provenance, one must know the direction in which it lies in respect to the basin of deposition and then to match the lithologic/mineral components of the litho-units, for which the source rocks are desired to be located, with rock types actually present in the indicated source area.

A review of the paleocurrent maps of the study area prepared by the author (Figs.30 and 32) shows that clastic sediments entered into the basin of deposition from a general south-westerly direction and were then dispersed within the basin under the influence of the pre-existing topography of the basin floor. Thus the source area which supplied the sediments to the basin must have been located south-west of the study area.

The distribution of the pre-Gondwana rocks south-west of the study area, and the broad paleocurrent pattern of the basinal rock is shown in Figure 33. It is observed that rocks of three age groups are present in the likely source area. The oldest are the basement rocks of Archaean age, comprising of granites and granite gneiss, which occur to the south and west of the study area. The same rocks occur beneath the Gondwana basin and often crop out as long, narrow, sub-parallel ridges from below the Talchir rocks.

Resting with a profound unconformity over the granite and gneisses and occurring to the south-west of the study area are a group of meta-sedimentary rocks referred to as Chilpighat "Series" (Pascoe, 1959, p. 161-163) and believed to belong to the Dharwar Supergroup (Lower Pre-Cambrian). The Chilpighat "Series" comprise of quartz schist, massive quartzite, mica schist, slate and inter-bedded greenstones and trappoid rocks. The equivalents of the Chilpighat "Series" also occur south and southeast of the study area (Sambhalpur-Raigarh-Sarangarh region) and consist of garnetiferous gneiss, quartz-garnet-schist, mica-schist and quartzite (Pascoe, 1959, p. 169).

Rocks of Upper Pre-Cambrian age occur to the southeast, south and south-west of the area in an enormous outcrop constituting of what is known in Indian Stratigraphy as the great "Chhattisgarh Basin". The rocks are generally undisturbed, unmetamorphosed and comprise of minor bands of oligomictic

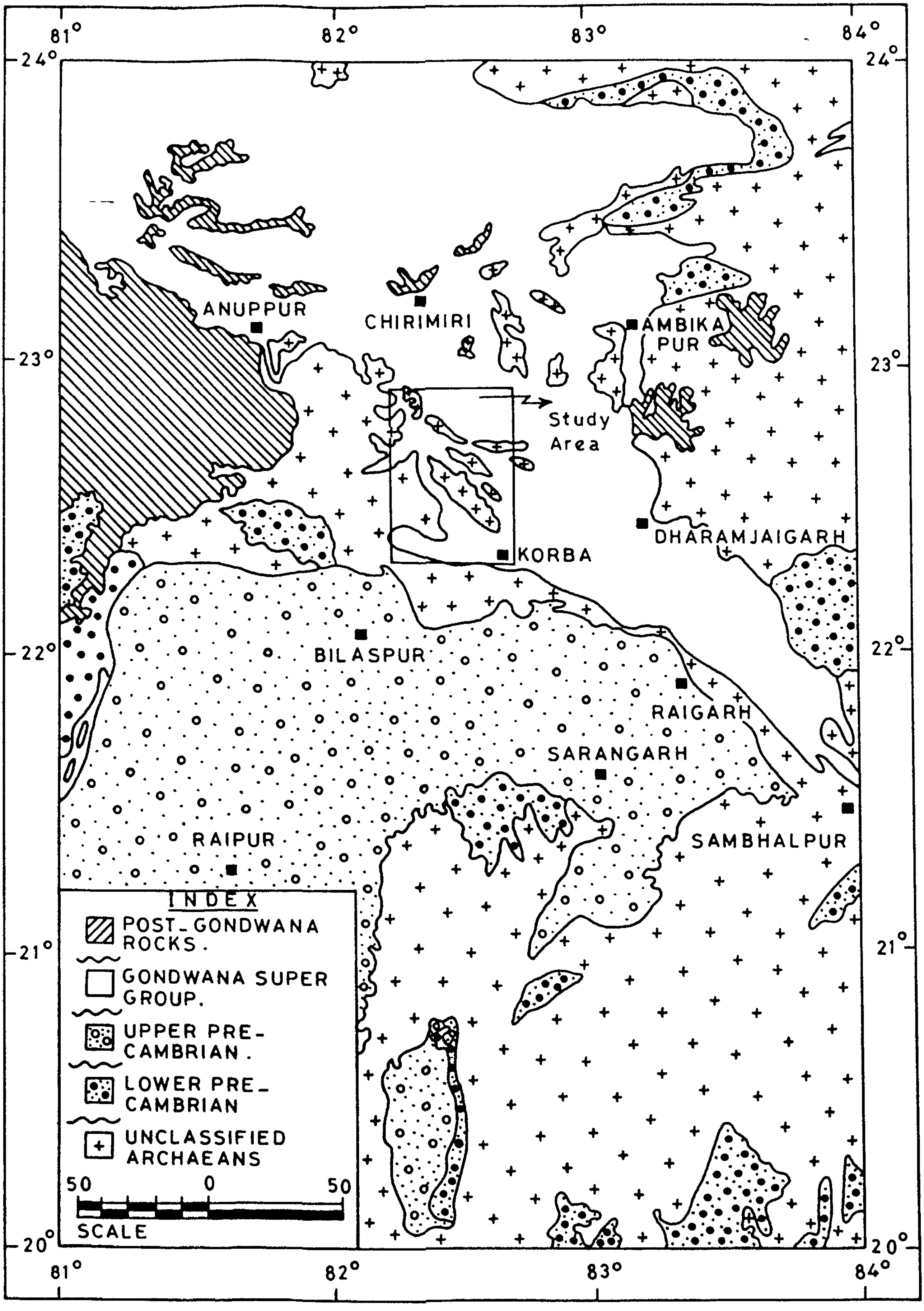


FIG.33. MAP SHOWING DISTRIBUTION OF ROCKS AROUND THE STUDY AREA

conglomerate, red coloured quartz arenite, shale and limestone. Dykes of dark green traps of unknown age, often cut across them.

This, then, was the lithologic and compositional mileu of the area which could possibly have served as the provenance of the Talchir rocks in the study area. That this area did indeed serve as the provenance is evident from a perusal of Table 37. Data show that there is almost exact compatibility of composition of arenaceous lithounits of Talchir Formation and the lithologies exposed in the suggested source area.

The heavy mineral assemblages occurring in the different sandstone facies and in the matrix of the two diamictite units deserve special mention. It is observed that the assemblages obtained from these distinct units, separated from each other in space and time, are remarkably similar in quality and quantity. Garnets constitute around 90% of the total heavy mineral crop although volumetrically the garnet-bearing rocks in the source area are not very extensive today. This relatively high percentage of garnets can be explained by, firstly, bearing in mind that the garnet-bearing rocks (now much reduced due to erosion) must have been much more extensively exposed in the source area during Talchir sedimentation. Secondly, by and large, the other litho-types exposed in the source area are quartzose in composition (quartzite, quartz schist, oligomictic conglomerate, quartz arenite) and themselves very deficient in heavy minerals. The preponderance of garnets is, therefore, due to paucity of other species.

Table-37 : Comparison of composition of arenaceous lithounits of Talchir Formation and lithologies exposed in the suggested provenance.

Lithologic composition of suggested provenance	Average composition of arenaceous lithounits of Talchir Formation				
	DIAMICTITES			SANDSTONES	
	Clast Lithology	Matrix Composition	Heavy Minerals	Composition	Heavy Minerals
Quartzose conglomerates Quartz-Schist Quartzite	Quartzite/ Quartz- Schist 43%	Quartz 84%	Garnet 89.5% Epidote 3.3% Micas 0.6%	Quartz 80% Feldspar 6% Quartzite/ Quartz- Schist 5%	Garnet 90.18% Epidote 2.10% Micas 0.18%
Granite, Gneiss	Granite/ gneiss 30%	Feldspar 6%			
Red Sandstone, shale	Red sandstone 18%	Quartzite/ Quartz- schist 3.2%	Opaques 5.0% Rutile 0.2%	Limestone and chert 4.5%	Opaques 2.10% Rutile 0.12%
Limestone	Limestone & chert 5%	Sandstone/ Limestone/ Chert 3.2%			
Mica schist, Quartz-garnet schist, garnetiferous gneiss	Schist/ Phyllite/ Slate 2%	Schist/ Phyllite Slate 2.6%	Zircon 0.7% Tourmaline 0.5%	Schist/ Phyllite/ Slate 3.5%	Zircon 0.98% Tourmaline 0.91% Apatite 0.51%
Greenstone and trappean rocks	Greenstone and trappean rocks 2%	Granite and gneiss 1.0%	Apatite 0.1% Titanite 0.1%	Granite/ Gneiss 1.0%	Titanite 3.18%

The greenstones and trap-rocks inter-bedded with the Chilpighat rocks must have contributed opaques (ilmenite and magnetite) to the basin as may have the mica-schist, epidote and micas.

Zircon and tourmaline may have been derived from two different sources. The well-worn grains of these minerals appear to be of multicycle origin, having been derived from older mature, quartz arenites of Chattisgarh basin. The occurrence of well rounded chert grains, limestone and quartz arenite fragments in sandstones and in the matrix of diamictites confirms the presence of older sediments in the source area.

The euhedral and/or sub-angular to sub-rounded grains of tourmaline and zircon, as also grains of apatite and titanite owe their derivation from the granitic/gneissic rocks.

On the basis of above findings it is surmised that the basement granites and gneisses of Archaean age, the metasediments of the Lower Pre-Cambrian Chilpighat "Series" and its equivalents and the Upper Pre-Cambrian Chhattisgarh rocks, all lying to the south, southwest and west of the study area, served as the source rocks for the sediments under investigation. The clast lithology of the diamictite units and the mineralogy of the sandstones and the matrix of the diamictites (including their heavy mineral assemblages) bear testimony to this surmise.

5.3. NATURE OF BASIN FLOOR

Before attempting to understand the sequence of events in the history of Talchir sedimentation, it is important to know the nature of the floor on which sedimentation was initiated and how, with time, it was modified. The important tools helpful in this regard are : 1) the present day distribution of Talchir rocks in the area, 2) the vertical and lateral variations in facies types and 3) the changing patterns of paleocurrent patterns through time.

An examination of the geological map of the area (Fig. 2) shows that Talchir sediments occur in depressions in the basement rocks and that the depressions are geomorphic and not tectonic. It is interesting to note that the present day valleys in the area coincide with the outcrops of Talchir rocks indicating that these are exhumed valleys (Casshyap and Srivastava, 1986).

In the immediate vicinity of the basin margin the Pre-Gondwana valleys show an ENE-WSW orientation and probably represent the valleys in the dissected margin of the Archaean upland. However, in the basin proper, northeastward of the dissected basin margin, the depressions between basement ridges trend NW-SE, Their shape and size must have been determined by the nature of the Archaean ridges which enclosed them. Near the basin margin these elongated depressions were shallower than those occurring in the more distal parts of the basin as evidenced by the thickness of sediments accumulated in them at localities near the basin margin (e.g. Jhulna nala section) and away from the margin (e.g. Tan Nadi, Bansajhal-Lathgarh nala and Ambikapur road sections). Thus, it appears that the Pre-Talchir basement ridges divided the initial basin into elongated "sub-basins" in which Talchir sedimentation was initiated. The probable nature of these basins and their evolution through time, as brought out in this study, is schematically shown in Figure 34.

The type of sedimentation that took place right one the basin margin near the dissected upland is illustrated by the section of the Talchir rocks exposed in the Jhulna nala. The total thickness of the sequence here is only about 14 m. That this thickness represents approximately the total thickness originally deposited at this locality is supported by the fact that the Talchirs here are seen to rest on the basement rocks and are overlain, at places, by the younger Barakar Formation (Fig. 2). The vertical and lateral distribution of lithofacies in this and other sections is schematically shown in Figures 35 and 36.

Sedimentation pattern in the more distal"sub-basins" are represented by sections like the one seen in the Tan Nadi - Gursian and Pondi-Bango areas. The total thickness of the Talchir sequence in these sections is of the order of about 42 m. Further, to the north in the Bansajhal-Lathgarh nala section, the total thickness of the Talchir sequence is about

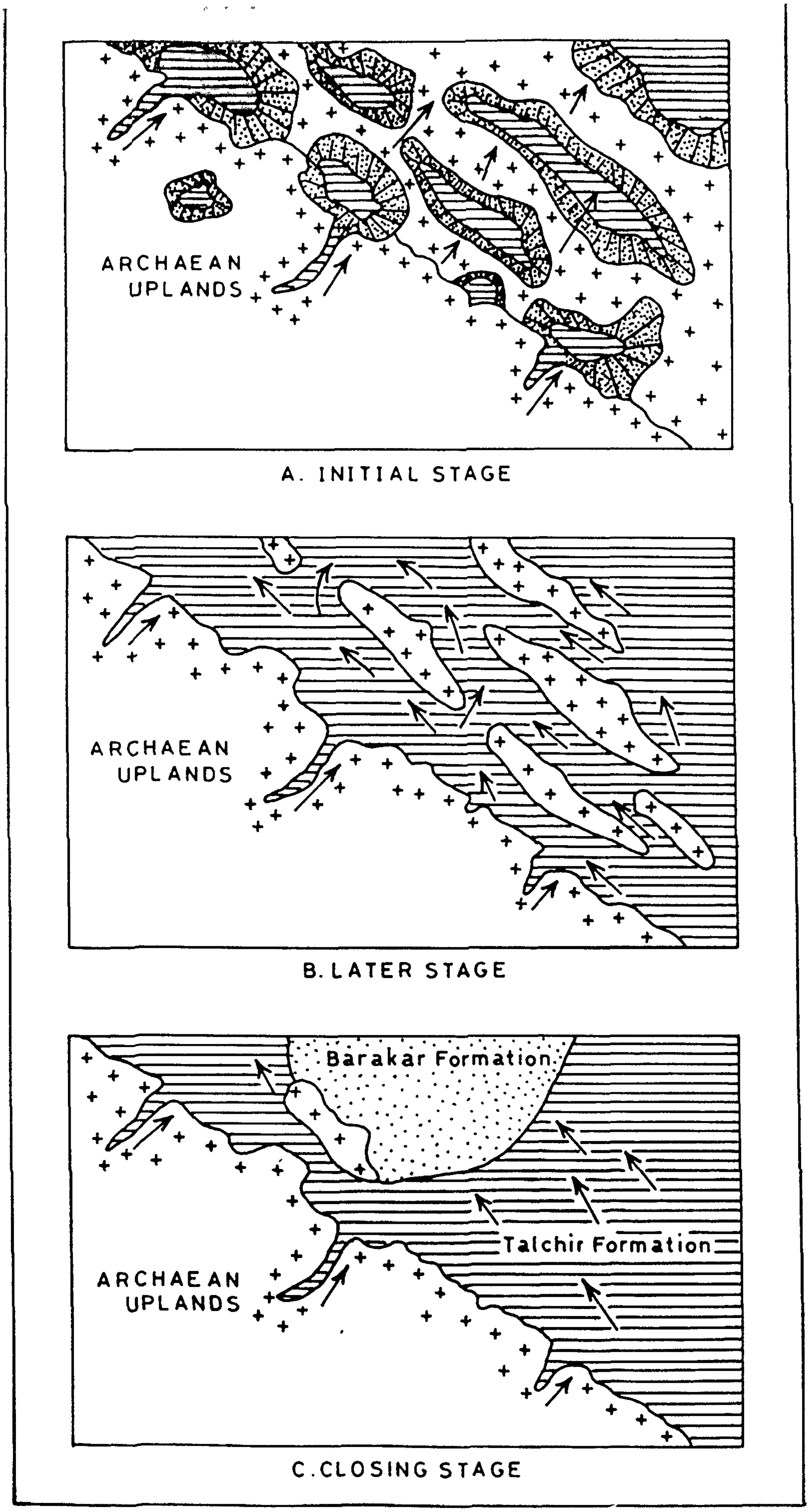


FIG.34. STAGES IN THE DEVELOPMENT OF THE TALCHIR BASIN IN THE STUDY AREA (SCHEMATIC).

77 m and in the most distal part of the section exposed in the study area, that is, the Ambikapur Road - Hasdo River section, it is of the order of about 105 m. However, the basic pattern of lithofacies distribution in all the sections named above remains the same and indicates sedimentation in bodies of standing water with several interludes of slight current action when fine to very fine sandstones and siltstones were deposited. It appears most likely that as sedimentation proceeded the smaller depressions were filled up and the smaller basement ridges were submerged under Talchir sediments. As a result, the sub-basins got interconnected and grew into much bigger basins. Evidence in support of this contention comes not only from the thicker and more diversified Talchir sequences in the more distal parts of the basin but also from paleocurrent studies. Paleocurrents in the upper diamictite and sandstone units occurring in the distal part of the basin show a zig-zag pattern following the outlines of the basement ridges indicating that the sub-basins on either side of the ridges had got connected in the later stages of sedimentation.

In the closing stages of Talchir sedimentation the basin floor was broad but still punctured by a few isolated peaks of disconnected basement highs. The rocks of the Barakar Formation in the neighbourhood of Korbi, overlapping on the basement Archaean ridges, byepassing the Talchirs supports this contention. The Talchir basin in the study area shows closed-basin-drainage conditions through most of its history and through-drainage conditions in the closing stages of sedimentation.

5.4. SEDIMENTATION HISTORY

5.4.1. Historical Background

The mode of origin of the Talchir rocks in general and the diamictite units contained in the basal part of this formation in particular, has been a matter of debate eversince these were first studied and described (Blanford et al., 1856).

Views regarding the origin of the Talchir diamictites have varied very widely. Blanford et al. (1856) considered the agency of ground ice as the only adequate means by which these could be formed. Hughes (1867, p. 8) opined that the Talchir rocks of Bokaro Coalfield were of marine origin. A marine origin for the Talchir rocks of Ramgarh coalfield was also advocated by Ball (1867, p. 8). He considered the "boulder conglomerate" at the base of the formation as a talus deposit resting on the flanks of metamorphic hills. Fedden (1875, p. 17) gave several new evidences in favour of the "ground ice" theory and strongly supported the view expressed earlier by Blanford and others. Blanford (1887, p. 49) slightly modified his earlier views and suggested that "the Talchir boulders were derived from rapid streams which were later on floated to the basin of deposition by winter ice". Oldham (1893, p. 160) reviewed critically the earlier views on the origin of the Talchir "boulder bed" and concluded that its formation was probably "due to the action of a true glacier". Fermor (1914, p. 167), Simpson and Ball (1922, p. 2) and Jowett (1925, p. 4) also supported a glacial origin of these rocks.

Fox (1930, p. 23; 1934, p. 103) was of the view that the "boulder bed" in the Jharia coalfield represented "resorted moraine material" and that a truly glacial origin was very doubtful. Gee (1932, p. 37; 1945, p. 30) considered the "early Talchir conglomerates" of glacial and fluvioglacial origin. Holland (1933, p. 66) did not consider all the occurrences of the "boulder bed" in peninsular India as "true tillites" and suggested that the agency of floating ice was far more likely to produce these deposits. Wadia (1939, p. 129) supported a fluvio-glacial origin for these rocks while Jacob (1952, p. 163)advocated a true glacial origin for most of the occurrences but suggested that those of the type area may be of fluvioglacial origin.

Based on modern methods of study of sediments, Casshyap and Qidwai (1974, p. 759) visualised a glacio-marine model in explaining the origin of the Talchir diamictite in Panch valley coalfields of Central India. Datta _et al_. (1977, p. 363) suggested that "Talchir sediments in the Koel valley area may be classed as periglacial deposits" while those of Son-Mahanadi valley (which, incidently, includes the study area) were considered by him "true glacial deposits".

It is seen from the above that the glacigene origin of the Talchir Formation in general and the Son-Mahanadi valley in particular, is established beyond doubt. The presence of a striated pavement in the study area (Ahmad et al., 1976; Casshyap and Srivastava, 1986), abundance of dropstones in fine clastics (this study), varves and associated lithologies in some parts of Son-Mahanadi valley (Rais, 1985), presence of shaped and striated clasts in diamictites in some Talchir basins of east and central India (Srivastava, 1961, 1967; Qidwai, 1972; Casshyap and Qidwai, 1974) and occurrence of features like rochés moutonneés on basement rocks (Datta et al., 1977) are irrefutable evidences in the face of which an ultimate glacial origin of the Talchir rocks cannot be denied.

5.4.2. Glacio-Lacustrine Model

The vertical and lateral variations in Talchir lithofacies (Figs. 35 and 36) and their textural, structural and compositional attributes in the different sections studied (and described in detail earlier), show remarkable similarity to such variations in deposits laid down in lakes in the light of criteria given by Collinson (1978, p. 67) for recognising ancient lake deposits. Thus :-

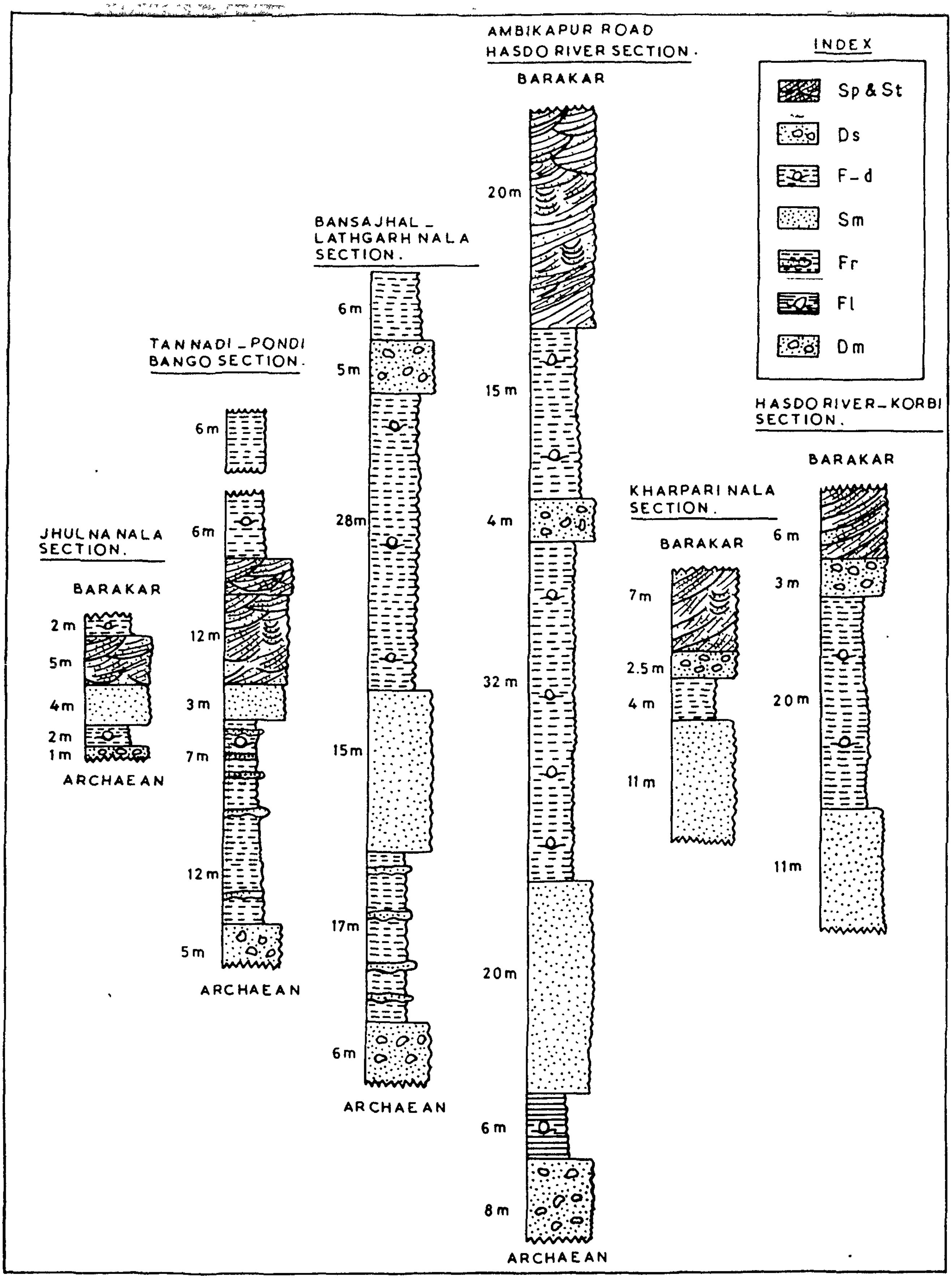


FIG. 35. LITHOLOGS SHOWING THE DISTRIBUTION OF TALCHIR FACIES

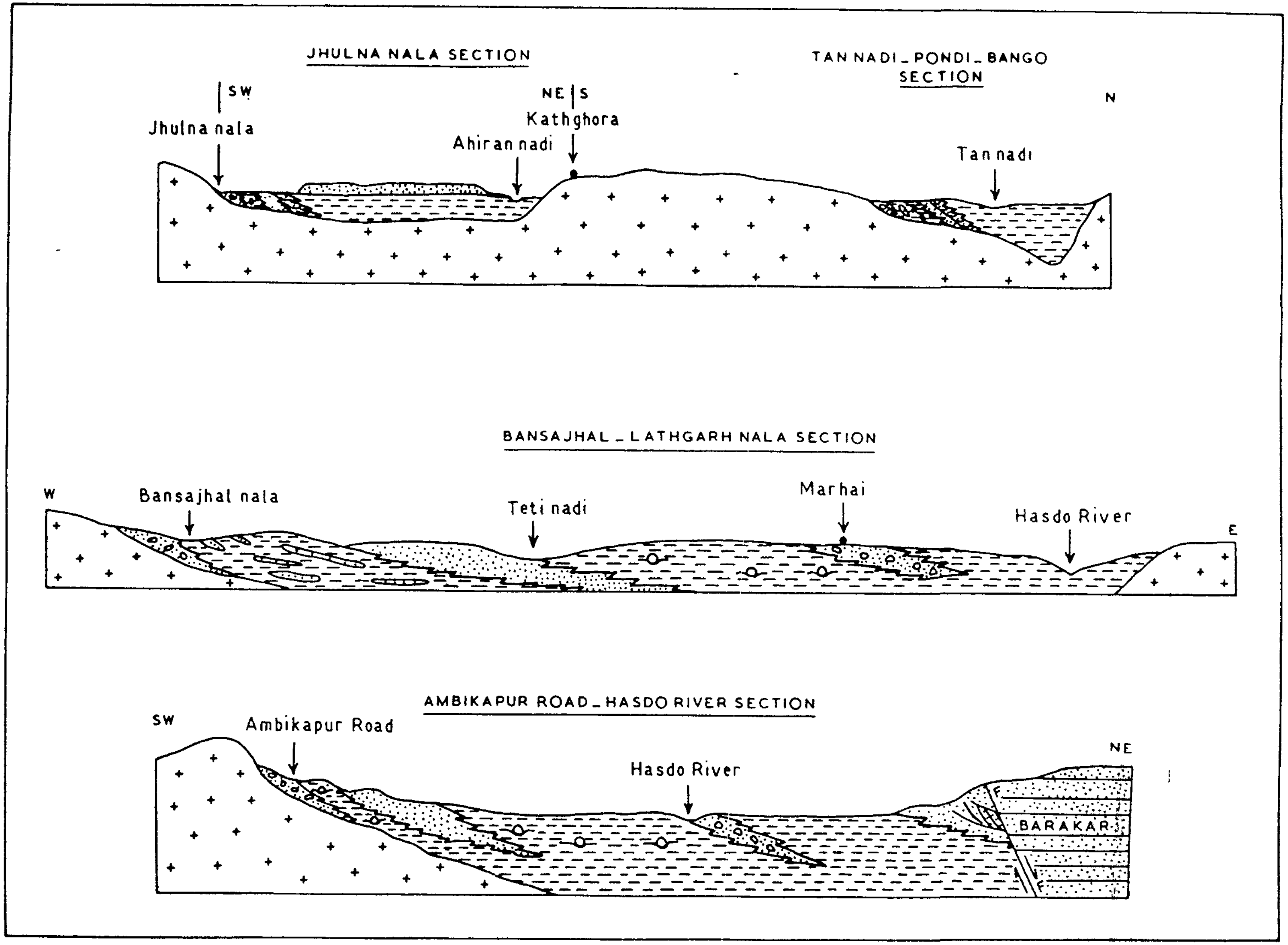


FIG. 36 SECTIONS SHOWING THE DISTRIBUTION OF TALCHIR FACIES IN THE STUDY AREA

1- Talchir sediments are dominantly fine grained. Most facies indicate deposition entirely from suspension. Sands, whenever and wherever present, are very fine to fine in grain size.

2- Two characteristic features are exhibited in most sections studied in respect of lateral variations in lithofacies and each one is considered typical of lacustrine deposits :
(a) There is rapid interdigitation of shore-line facies and
(b) There is distal fining of sediments away from the source of sediment supply.

3- Coarsening upwards sequences are seen, at least partly, in most sections. The upper part of each sequence shows increasing evidence of bottom currents. Very fine to fine-grained sandstones are often cross-stratified and occur inter-bedded with ripple marked/cross-laminated siltstones suggesting a gradual transition of the lakes into a flood plains.

4- Signs of emergence, such as occurrence of thin layers of pebble beds and thin sun-cracked layers of mud are common.

5- Sediments are compositionally immature. Sands are lithic to arkosic in composition.

6- Sediments are often highly calcareous.

Over this broad lacustrine environment was superimposed a glacial environment. The glaciers which gathered on the

Chhattisgarh highlands southwest of the area, descended on this network of lakes directly as a result of basin geomorphology. These lakes, therefore, may be designated as "proglacial" rather than "periglacial" because there is evidence to show that they were in direct contact with the ice margin and received a major part of sediment direct from glaciers or through ice rafting. In contrast "the periglacial lakes are not in direct contact with an ice margin and are fed by braided stream systems" (Eyles and Miall, 1984, p. 20) for which no evidence is available from the study area.

Talchir sedimentation in the study area was, therefore, initiated in such isolated proglacial lakes of variable depths depending upon their geographical local in respect of the basin margin. Through time, these lakes grew in size by coalescing together. In the closing stages of Talchir sedimentation, flood plain conditions prevailed.

5.4.3. Interpretation of Lithofacies

The Talchir sequence in the area under investigation comprises of seven basic types of lithofacies namely, massive (basal) diamictite, mudstone with or without dropstone, inter-bedded shale-siltstone/sandstone, massive sandstone, splintery shale, stratified (upper) diamictite and cross-stratified sandstone. Their order of appearance from the base to the top is shown in the flowsheet in Figure 37.

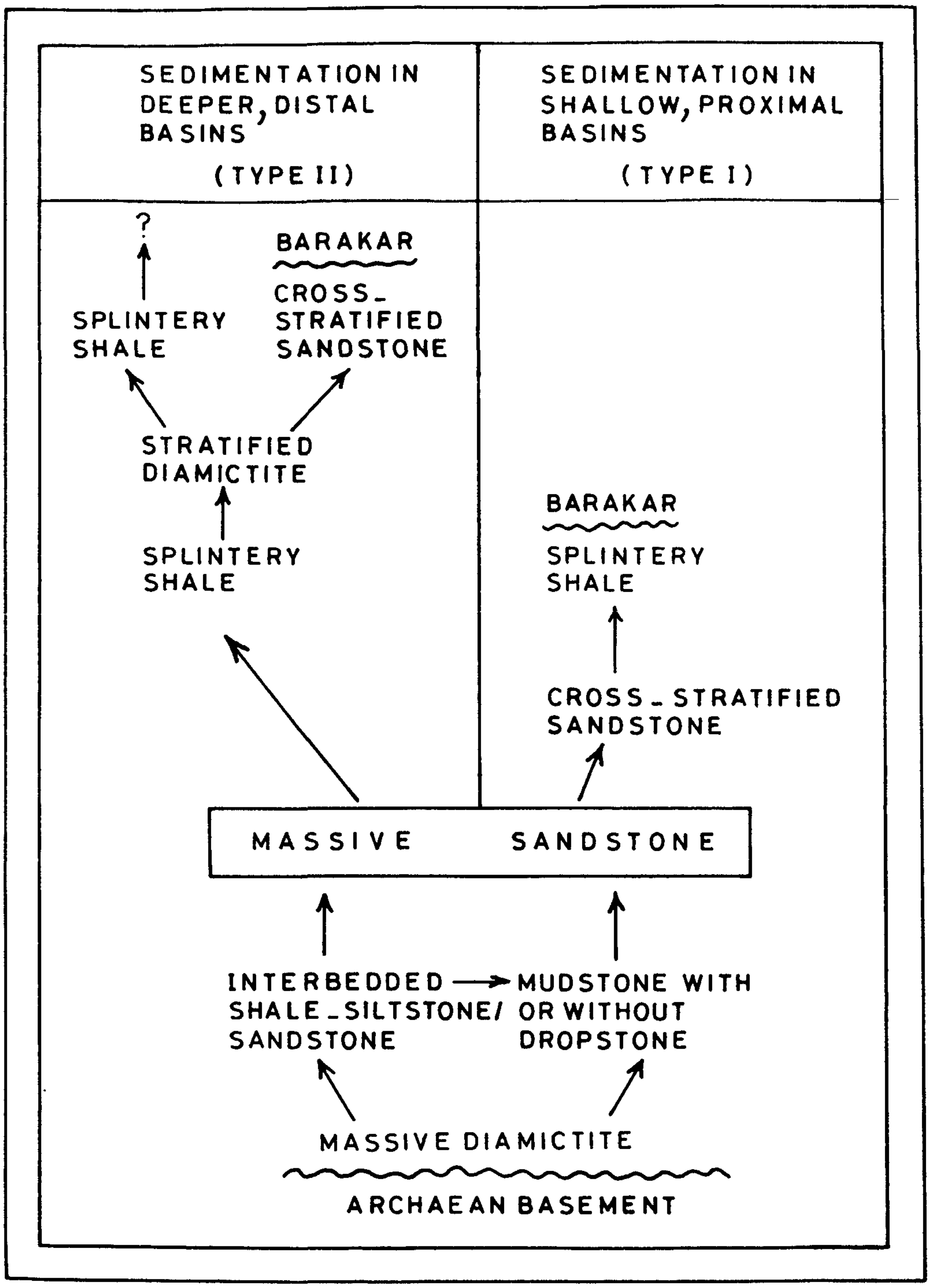


FIG.37. FLOWSHEET SHOWING ORDER OF APPEARANCE OF LITHOFACIES.

MASSIVE (BASAL) DIAMICTITE (Dm)

The massive diamictite is completely devoid of stratification and invariably occurs at the base of the Talchir Formation. Its thickness varies from 1 m to 5 m.

This diamictite is polymictic, poorly sorted, and abounds in detrital, clayey matrix. Clasts, which are mostly of local derivation, are sub-angular to sub-rounded and constitute about 8% of the total volume of the rock. Studies on clast orientation indicate that a well developed anisotropic fabric exists. The long axes of clasts in most cases show preferred orientation in two mutually perpendicular directions comparable to till fabric (Holmes, 1941; Harrison, 1957).

The massive diamictite thus shows the characteristic features of a typical basal till. The presence of ice contact features like crescent marks and sub-parallel striations on bed rocks (such as those seen in the Tan *Nadi* section) and *rochés moutonneés* in neighbouring areas (Datta *et al.*, 1977, p. 361) confirms the idea that the basal diamictite was formed directly as a basal till without any subsequent reworking. They fall under the category of true tillites as defined by Boulton (1981). Such deposits have been considered by Boulton and Eyles (1979) to have formed during the retreating stage of glaciation.

LAMINATED MUDSTONE WITH OR WITHOUT DROPSTONE (F1)

In the Jhulna nala and Ambikapur road sections, the massive (basal) diamictite passes into laminated mudstone which usually displays occasional dropstones. The contact between the two facies is usually gradational. It is highly variable in thickness, being 2 m to 7 m thick in proximal basins (e.g. Jhulna nala and Tan Nadi sections) and 17 m thick in distal basins (e.g. Ambikapur road section).

The mudstone is finely laminated and contains dropstones of the same lithology as the clasts present in the massive diamictite. Further, the colour, composition and texture of the mudstone is identical with the clayey matrix of the underlying massive diamictite.

The fine and persistent laminations seen in this facies and the absence of any current structures in them, suggests that the mudstone was deposited subaquously in a standing body of water devoid of all turbulence. Clasts were released from the floating icebergs which now occur as dropstones.

Only in the uppermost part of this facies, lenses of ripple cross-laminated siltstones occur indicating slight turbulence and reworking of the fine clastics. This facies passes upwards gradationally into massive, fine to very sand-stone indicating further shallowing of the basin and consequently a greater degree of reworking.

INTER-BEDDED SHALE-SILTSTONE/SANDSTONE (Fr)

In the Tan Nadi and Bansajhal nala sections, the massive (basal) diamictite passes directly into an inter-bedded rhythmic sequence of parallel laminated shale-siltstone/fine sandstone. The shale component dominates the lower part of the sequence while siltstone/sandstone are dominant in the upper part. In the Tan Nadi section, the uppermost part shows the occurrence of small flat-topped sand-filled channels trending NW-SE. However, in the Bansajhal nala section, no such channels are seen, sandy intercalations are few and the siltstone beds show ripple cross-laminations. Thin, discontinuous lenses of carbonate mud are common in the shale units in both the sections mentioned above.

This lithofacies gives evidence of having been deposited initially in quiet waters immediately after emplacement of the basal tillite in the same manner in which the mudstone was deposited in some parts of the area. However, there were intermittant but short-lived episodes of slightly turbulent conditions resulting in the depostion of fairly continuous beds of siltstone/fine sandstone exhibiting ripple cross-laminations. Such conditions were more recurrent when the upper part of this facies was deposited as indicated by the dominance of the silty and sandy lithologies.

In the shallow, proximal basins, as exemplified by the Tan Nadi section, there is evidence to show that during the last stages of deposition of this facies, the lacustrine conditions started giving way to open drainage conditions. The presence of small sand-filled channels, trending parallel to the confining Archaean ridges running in the NW-SE direction support this conclusion. In the distal basins (e.g. Bansajhal nala section) the degree of shallowing was much less and perhaps the open drainage conditions were not established at this stage.

MASSIVE SANDSTONE (Sm)

This facies occurs in all the sections studied and is of variable thickness (4 m - 14 m). It is fine to very fine in grain size, moderately sorted and varies in composition from lithic arenite to sub-arkose. Bedding is not distinct in this facies and it displays no sedimentary structure. In sections where it rests over the mudstone, its lower contact is often loaded but its contact with the inter-bedded facies is channelled.

In its uppermost part, it exhibits thin layers of densely packed, well-sorted, sub-angular to sub-rounded clasts of the same composition as are present in the massive (basal) diamictite. In juxtaposition with the thin pebble layers, there occur patches of green splintery shales.

It seems likely that the deposition of this facies took place in response to shallowing of the lakes as a result of rapid filling by glacially derived fine sand. Rapid dumping of fine sand over hydroplastic clay of the underlying facies caused large scale loading of the base of this sandstone body and perhaps was also responsible for its massive character and lack of current structures.

The thin pebble layers on the top of this facies perhaps represent the reworked clasts of the basal diamictite deposited in glacier fed, stream channels while green shales occurring in juxtaposition represent the inter-channel fine clastics (levees?)

In the marginal areas of the basin, this facies passes gradationally upwards into a 5 m to 12 m thick sequence of cross-stratified sandstone with minor shales. This passage marks the establishment of a fluvial system in the marginal belt of the basin and also the end of Talchir sedimentation in this belt.

However, basinwards Talchir sedimentation continued in a broad lacustrine environment as is indicated by the passage of massive sandstone into a 12 m to 32 m thick sequence of splintery shales.

SPLINTERY SHALE WITH OR WITHOUT DROPSTONE (F-d)

As mentioned above this facies rests on the fine grained massive sandstone in the distal parts of the basin in the study area. The shale is thinly parallel laminated and often contains a few dropstones here and there. In its upper part, bands of siltstone/fine sandstone occur as intercalations. In the Hasdo river section at Korbi, slumped masses of folded and contorted blocks of shale, siltstone, etc. lie scattered within the shales.

The textural and structural features of this facies point to a turbulence-free environment of deposition. The earlier tendency of shallowing of the basin seems to have been reversed at this stage perhaps as a result of damming of the lakes by glacial debris. The glacial agencies were still active is shown by the presence of dropstones and slumped masses of siltstone etc., in the body of the fine clastics. Casshyap and Srivastava (1986) have interpreted the occurrence of such slumped masses as blocks of tills dropped into the basin below by floating ice or as "frozen glacial debris slumped from shelf into deeper part of the basin" caused by "oversteepening of the till front or push by the ice itself".

STRATIFIED (UPPER) DIAMICTITE (Ds)

This facies is 2.5 m to 5 m thick and shows distinct to crude stratification. It comprises of an assemblage of clasts of the same lithology as are found in the massive diamictite.

However, the clasts are better sorted and better rounded than those in the massive variety. The matrix is sandy and moderately sorted. The clast fabric is usually unimodal and shows a stronger degree of preferred orientation. In its upper part, it exhibits lenses of cross-stratified sandstones.

As mentioned earlier, this lithofacies usually occurs as big and small lenses within the laminated shales. Its association and sedimentary characters indicates that it might have been deposited as a result of reworking of older tills in shallow water channels below grounded ice or floating ice as visualised by Dreimanis (1979) and Boulten and Eyles (1979).

CROSS-STRATIFIED SANDSTONE (Sp and St)

This sandstone facies occurs at two different horizons in the Talchir sequence in the study area. In sections representing the shallow proximal part of the basin (e.g. Jhulna nala and Tan Nadi section), the cross-stratified sandstone is 5 m to 12 m thick and rests on the massive sandstone with a gradational contact. On the other hand in sections representing the deeper, distal parts of the basin (e.g. Ambikapur road, Kharpari nala and Korbi section) it is 6 m to 20 m thick and rests on the stratified (upper) diamictite.

The paleoflow pattern in this facies is unimodal fan-shaped in most cases and is oriented in the northwesterly direction. The outcrop to outcrop variation is small and variance value range between 147 and 3942. It appears most likely that this facies represents the establishment of a wide spread fluvial environment. It also marks, the end of Talchir sedimentation and the dawn of a truly fluvial niche so characteristic of the Gondwanas.

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